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ABSTRACT

Videodisc technology carries great promise for coping with current and future educational problems, and advancements in the area of individualized instruction have proven effective in dealing with educational problems where large scale efforts based upon traditional methods have met with little success. Individualized videodisc instruction has the instructional strengths of books, motion pictures and television, and the computer. With further advancements in its technology and public use, the videodisc can become a highly cost effective method of instruction; however, government support through the funding of technological research and implementation programs is crucial for the advancement of this valuable educational resource. This paper includes descriptions of technical aspects of the videodisc, as well as brief discussions of the strengths and weaknesses of various educational technologies, cost analysis for interactive courseware, and a bibliography. (CMV)

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THE PROMISE AND INEVITABILITY OF THE VIDEODISC IN EDUCATION

A Paper Submitted to
The National Institute of Education
by

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I. THE PROMISE OF TECHNOLOGY IN RELATION TO CURRENT EDUCATIONAL PROBLEMS

A Brief Contemporary Educational Overview

The videodisc is a product of technology, and before analyzing the specific impact that the videodisc is likely to have in education this paper will present a rationale for an understanding of the coming importance of technology for education.

The late 1970's are proving to be a difficult time for education. The primary problem appears to be the inability of the standard educational institutions at every level to educate a large enough segment of the population to a level where the members can find meaningful work in a post-industrial society where computational and verbal skills are a prerequisite. As Bell has pointed out in his book, The Coming of the Post-Industrial Society, the dominant industry of the first third of this century was U. S. Steel. The middle third saw the ascendancy of Ford and General Motors, while IBM will probably dominate the last third. Quite obviously there is an ascending order of educational literacy needed in the types of job markets available as the century has progressed.

A glance at some of the statistics that have been released this year suggests that education is having a difficult time meeting these increasing literacy demands. One study by the National Assessment of Educational Progress has indicated that 42% of the 17-year-old black students in American society are functionally illiterate. This year (1977) New York City also released some

statistics that show that 45% of the high school population cannot read a simple paragraph for comprehension, and an additional 23% barely can. This means that over two-thirds of New York City high school students are suffering from serious educational deficiencies. Another National Assessment study has shown just recently that one-third of the Hispanic 17-year-old students are in the tenth grade or below as contrasted with one-tenth of those who are white. Thus the students who would naturally have the most difficult time entering the work force are having the least educational success. The unemployment figures fluctuate, but not too many months ago 42% of the black teenagers were out of work. Certainly there is no precise correlation between the 42% of the black teenagers out of work and the 42% who are functionally illiterate at age 17, but there undoubtedly is a reasonable relationship between these and similar figures.

To some extent this is a discouraging period for the educational leadership and those who are charged with the responsibility of alleviating educational problems. The reason there is a gentle sense of malaise is that most of the standard remedies have been tried, and a great deal of money and effort has been expended over the past few decades with few encouraging results. Between 1950 and 1975 the percentage of the Gross National Product spent on education rose from 3.4% to 7.4%, an increase of almost 120%. Despite this enormous outpouring of funds through the willingness of the taxpayers, the pupils' scores have not improved and the problems are as severe as before, if not more so. For many years the educational establishment believed that if sufficient compensatory programs were funded and

obvious inequalities done away with, a solution could quickly be effected. Unfortunately, the financial improvements not only have failed to provide relief, but a very detailed study by Coleman which was to have documented the inequalities in our educational system failed even to find them. Thus two great certainties that were practically universally believed by our educational leadership were found to be invalid, and to some extent these findings have traumatized the planning processes of the leadership. The Coleman findings were so surprising that they have stimulated a great deal of interest in research and, to a lesser extent, testing. The research model has been an important one for the past few years and has served two useful purposes:

(1) It has helped us begin the collection of objective data in a field where there was too little.

(2) During the recent period of confusion and stress, it has provided a sensible way to focus the energies of the educational leadership.

As helpful as this research will be, however, it cannot solve any educational problems. Only a positive program can achieve this, and here the Coleman data seems to indicate that this will not be an easy task since the system appears to have no glaring inequalities that are readily amenable to improvement.

The Central Educational Problems

There are a number of fundamental educational problems that appear to be defining the limits to the traditional innovative improvement strategies. The most important of these limits is the

problem of work. Stated briefly, there is too much work for the teacher to do to improve the educational process significantly. Since the elementary school is key to a successful educational start, a brief analysis of the elementary school tasks will be helpful.

A good elementary school teacher has at least four critical tasks:

(1) Presenting accurate information at an appropriate level for the individual students.

(2) Giving those students trials with appropriate feedback until mastery is reached.

(3) Providing an atmosphere which encourages students to work.

(4) Participating in a replication process where the teacher uses outstanding programs and in turn passes on programs worthy of replication to others.

Taking these points in order, we can quickly see how work ceilings are being reached:

(1) A good rule of thumb for elementary school classrooms is that the students' ability levels in an elementary school class vary by as many years as the grade level being analyzed. Thus in the sixth grade there are apt to be six years of difference in student abilities in a given classroom. Similarly, in an eighth grade there are apt to be eight years of difference. Thus in an eighth grade class some students may be at the fourth grade reading level while others are at the twelfth. Sectioning students by ability level, where permissible, can help alleviate some

of the problem, but even in a supposedly homogeneous range of students there are enormous differences in learning styles and the ability to master different kinds of materials. Some students cannot learn by reading, while others are unable to hold any information of an audio nature. Given the constraints of time and physical stamina, the teacher faces an impossible task in individualizing instruction for the extraordinary range of students that he or she faces. Teachers traditionally handle this range by an approximation strategy which forces them to teach at an average level for the whole group, even though they realize that most of the information is inappropriate for many of the class members.

(2) Another important manifestation of the work problem appears when the teacher attempts to give the student a trial at the material by asking questions and giving appropriate responses. Student trials with appropriate feedback are the key to mastering materials. Because of the number of students a teacher has to interact with and the anti-intellectual environment of many city classroom populations, the average student is getting very few, if any, trials per day. This problem is likely to increase as class size increases. When one student is asked a question, given time to respond, and has the teacher in turn respond to him, many of the class members become bored during the process and grow restless. Thus even though individual

trials are badly needed, they frequently are at odds with the group interest. The larger the section, the greater the reluctance of the teacher to sponsor a process that will bore the group.

(3) Teachers are also approaching the work limit in their ability to motivate the student population for which they are responsible. On the surface the problem seems most acute in city school systems where the intellectual traditions of the minority populations are frequently at odds with the desires of the school administrators. While the parents might want their children to have an excellent intellectual education, the peer modeling problem seems to circumvent adult wishes. In truth, the problem is almost as serious in rural settings where the cultural bias is toward useful careers that are increasingly disappearing from the work force. For generation it was enough for rural students to learn "enough" in school to handle construction and farming tasks, but these job markets are not the ones where growth will be taking place.

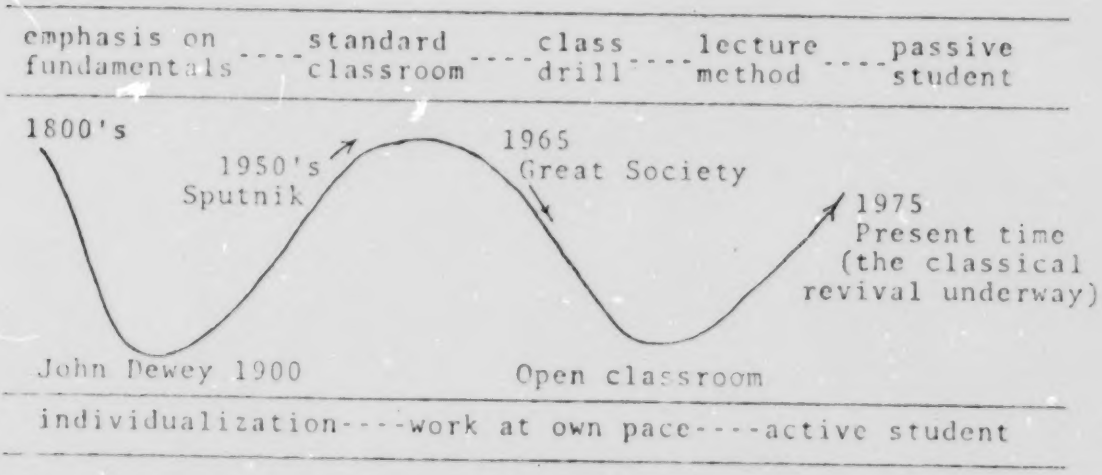
Unquestionably television is contributing to the problem. With the average child seeing about a thousand hours of television per year, emotional and entertainment horizons are opened to him in a powerful visual and audio sense that the average teacher cannot match.

(4) Because the work demands of the first three points are so severe, teachers have a minimal amount of time to become

involved in highly innovative and new programs, much less to become sponsors of them. Furthermore, since such replication depends on an oral tradition where one teacher attempts to train others, who in turn must train others, there is inevitable shifting of the primary goals of the innovation as the program spreads out from its original center. No sponsor of an original program can ever be involved with the ever-increasing number of people who will be using it. And as in the tradition of story telling, something is lost in each telling.

There is an interesting dichotomy in educational biases that generally splits the educational sector into two camps. On the one hand there is the liberal movement which encourages this individual instruction at each student's own pace. The movement surfaces under various progressive educational titles historically, be it Rousseau, Dewey, or the Open Classroom. Pitted against the liberal movement is a more classical, structurally oriented movement that approves of lecturing, quizzing, testing, and drilling the fundamentals in a highly structured atmosphere. In fact, neither system works well alone, and historically as one fails the other surfaces in an endless cycle. During the last century we generally had a structured system, and then at the turn of the century John Dewey sponsored progressive education to rid education of the faults of excess structure that kept students passive and ignored their individual differences. Following the Second World War we had a return to the fundamentals, particularly after Sputnik. This was followed by the generous outpouring of funds

for the "Great Society" and the rediscovery of the open classroom with its liberal emphasis on behalf of the child's individuality. Now we are in a classical cycle again as we are rushing back to the fundamentals. The cycle can be pictured this way:



This diagram is a gross oversimplification of a very complex educational history. What it is intended to exhibit is that we have not been facing a philosophical problem all of these years, but a work problem. Each of the two extremes lacks enough labor to use the process successfully and thus, like an endless sine wave, educational history plays itself out.

Solving the Work Problem

Assuming that a reasonable efficiency has been reached in a process, there are at least three historical approaches used to increase the amount of work being done:

(1) Use capital to purchase more workers.

(2) Work at strategies to increase productivity.

(3) Where applicable and economical, harness technology to do more work.

Turning to these points in order, we note:

(1) We are either at or close to a financial ceiling that society is willing to commit to adding more workers to the educational work force. Because of budgetary constraints, many cities and towns are cutting back on the number of teachers being employed rather than adding them. Similarly, most colleges are attempting to increase the student-to-teacher ratio rather than to lower it. A declining birthrate has exacerbated this problem and many school systems find themselves with an excess of physical plant and teachers. Thus it appears that this is not a propitious time for exercising option (1) to increase the amount of work being done on behalf of students.

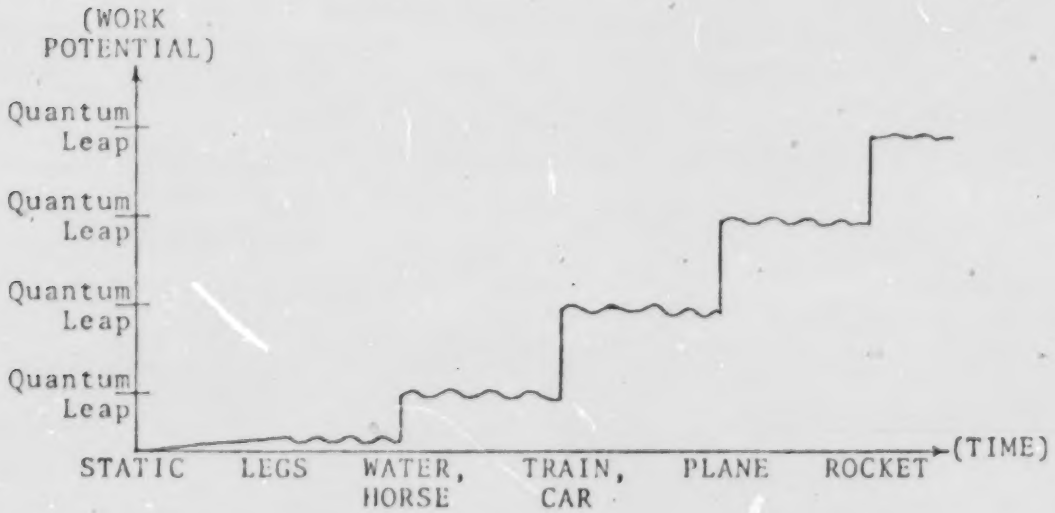
(2) Because of the financial strains facing education at this time, we can assume that teacher productivity will probably be pushed to its maximum efficiency. There will naturally be critics who feel that teachers' productivity is not sufficient, and teachers, in turn, will have reservations about teaching too many students simultaneously. Probably there will be some excesses in both directions, but the ratios will probably sort to a reasonable balance between teacher productivity and the needs of students to be treated in a personal way.

Patrick Haggerty, the former chairman of Texas Instruments, has made some very pertinent comments relating to learner productivity. Industry has been particularly sensitive to learner productivity because of the expense entailed in training its personnel. They must pay the people while they are being trained as well as teachers to train them and personnel to do the work in their absence, not to mention the cost of developing the educational programs themselves. William Norris of Control Data has estimated that industry spends $100 billion a year in educational projects, the same amount spent by the entire educational system.

The main thrust toward learner productivity has come through an attempt to individualize instruction and allow the student to actively work at his or her own pace instead of sitting passively while receiving instruction. There are various manifestations of this approach, such as the open classroom, programmed instruction, individual prescribed instruction, etc. Each of these has met with limited success because there is some aspect of the teaching process where they require more work than the system can deliver. An open classroom, for example, can start each student working on his or her task, but usually a teacher has difficulty monitoring and providing adequate feedback and constant motivation for all of the students who are embarking on

different paths at different paces. Monitoring, encouraging, giving feedback, etc., become too large a work problem for the single teacher. In addition, the open classroom is not as amenable to working with students with more advanced concepts. Explaining the complexities of a physics or calculus problem individually to a great number of students at different times requires too much work for the time allowed. Thus the open classroom approach is generally restricted to the lower elementary school grades.

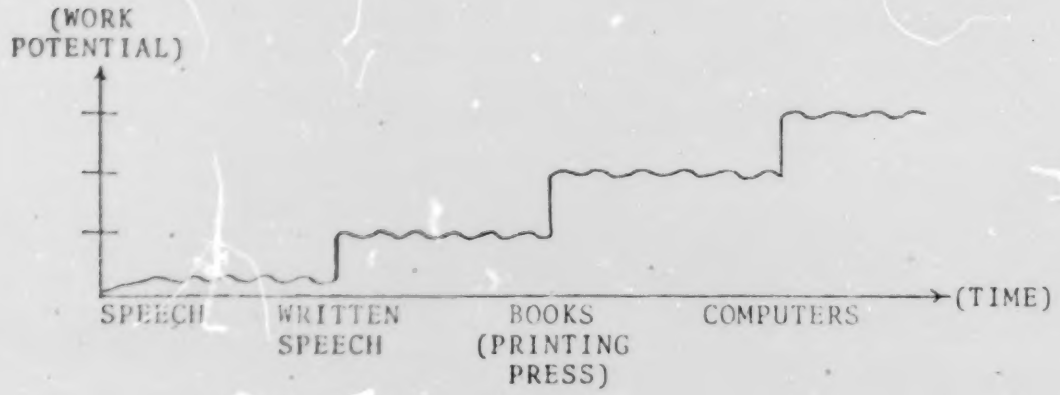
(3) The power of technology is derived from its ability to allow a human to do more work. Occasionally, a new technology appears which is applicable to a certain process and allows, therefore, a quantum leap to be made in the amount of work that can be done by a worker in that field. For a simple example of this, let us analyze the work of transporting a man from one place to another in terms of the various processes man has invented. A graph should help clarify this point:



What this graph says is that man has occasionally invented a process, particularly with technology, that allows him to make a quantum leap in the amount of work he can do in transporting himself or others. There are two important and related points to notice about the graph: the minor fluctuations possible in each process (illustrated by ~~~) and the notation that between each process a quantum leap has been taken in the amount of work that can be accomplished. What should be noticed here is that the fluctuations at each level, representing the usual variations in efficiency between poor and good utilization, come nowhere close to the energy differences between the various levels which are separated by vast differences in potential. Thus no amount of careful breeding, attention to diet, training, conditioning, etc., of a great horse can make it even close in work transportation potential under normal circumstances to even a badly used mediocre car.

Most of man's efforts to accomplish work have to do with improving his efficiency in whatever process he is using, but once a quantum leap is made, no amount of polishing the previous process will enable it to compete with the amount of work the new process can handle. In other words, man is foolish to concentrate on the "efficiency" variable once a new "leveraging" variable has been discovered. Thus a more efficient and better trained archer will lose to a rifle just as a cavalry will be defeated by tanks.

Applying this analysis to education, we can see how few quantum leaps have been made. Experts might differ about what the quantum leaps are, but I think the general graph illustrates the point well:



Essentially, because there have been so few quantum leaps in educational work efficiencies, schools use the same teaching process that has been followed for 500 years. There are a few frills, such as overhead projectors, record players, and an occasional movie, but the instructional process is basically the same as it has been since the invention of the printing press about 500 years ago. If we were to remove the books from schools, the process would be the same one we have known for all of recorded history. Thus, except for the printing press which allows a teacher to leverage his work into a portable and permanent form that others can use without his presence, education has been almost totally stagnant in work improvement strategies from the inception of recorded history.

During the past thirty years there has been a fundamental technological revolution that has seen the birth of products that should be applicable to the educational process. The most powerful of these technologies is the computer, and it derives its power from its capacity to do work at close to the speed of light. Since the speed of light is an apparent theoretical limit, one can surmise that any device which can harness its speed will be taking a quantum leap that approaches ultimate threshholds. An excellent earlier example of harnessing the speed of light can be derived from our use of electricity in our communication systems. The telegraph, telephone and radio obsoleted in a flash the ability of the pony express or locomotive to compete in delivering messages. A message could be completed coast to coast before the horse had its foreleg off the ground or the locomotive had its wheel turn one revolution.

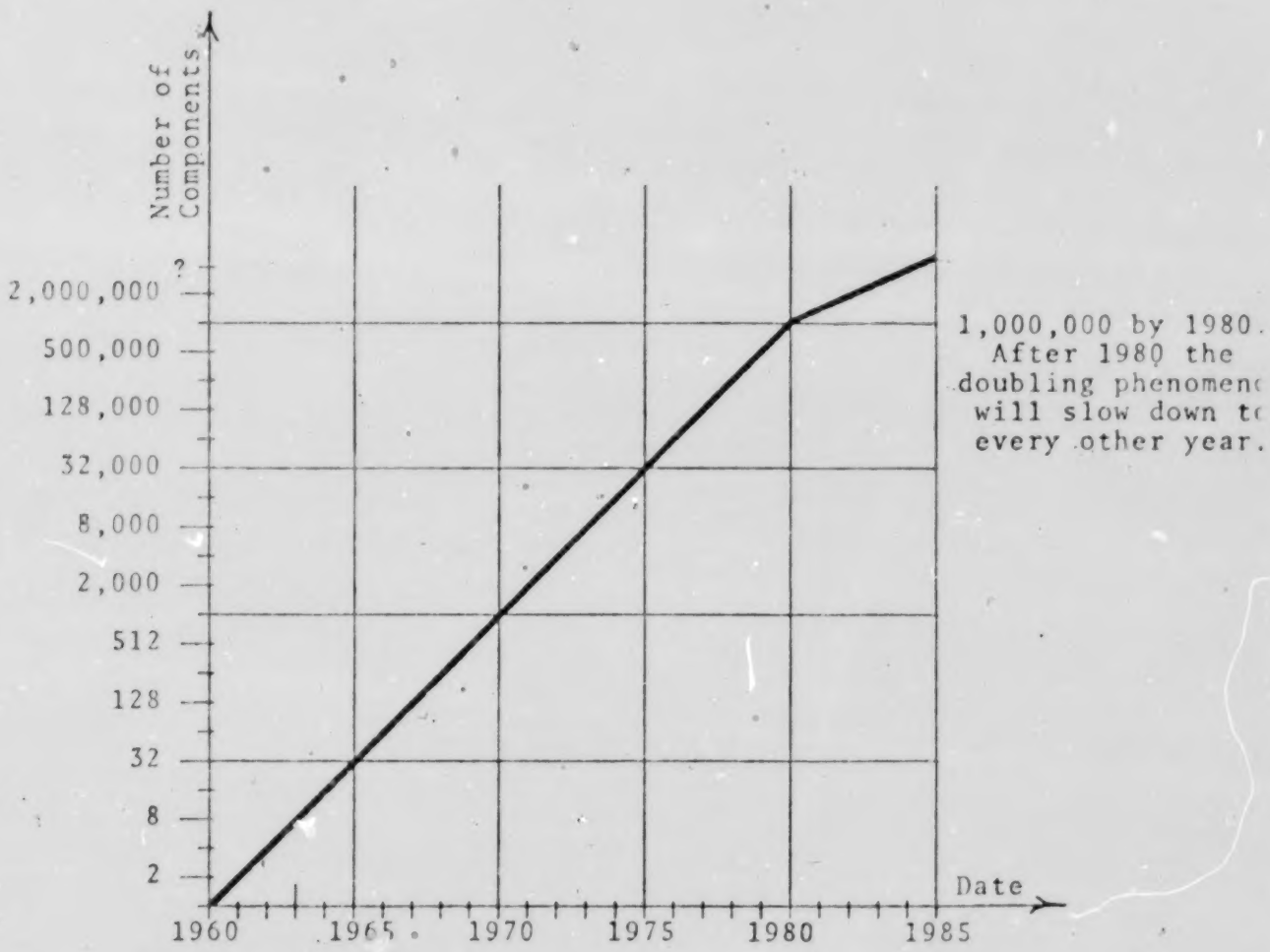
Cost and Technology

One of the severe limiting factors in the use of technology is cost. The average person drives rather than flies to work even though the faster technology is available. Similarly, rockets have not yet been harnessed for coast to coast trips by even the most affluent businessmen or governments.

One of the early problems in harnessing the computer to education was the financial cost. In the mid 1960's a computer might cost $300,000 to purchase that could support six terminals. Thus a terminal cost in the neighborhood of $50,000. Ten years later in the mid 1970's a $300,000 system might support sixty terminals for

roughly $5,000 a terminal. Within a few years the price will be $500 a terminal. Recently, for example, Radio Shack has announced a computer, a keyboard, a CRT (a black and white cathode ray tube screen) and a tape cassette interface, all for a price of $600.

Underlying, and indeed forcing the price reduction, is the technological innovation being bred by the semiconductor manufacturers as they work to place electronic components (transistors, resistors, capacitors, and diodes) in a small 1/4" piece of silicon. The following graph should help clarify what has been happening to the semiconductor industry since 1960:



What the graph illustrates is that every year since 1960 the number of electronic components that can be placed on a piece of silicon approximately 1/4" square has doubled. Thus by the end of 1977, 2^{17} of 128,000 components will be able to be put on a chip this size. Semiconductor experts generally agree that this doubling should continue until about 1980, when the process should start to slow down to a doubling every two years and continue well into the 1980's. The economic implications of the doubling process are that the price remains relatively constant after the technology of a new doubling has been mastered. By the mid 1980's this means that powerful computers with up to a million bits of memory will be all on one chip and cost less than $100.

Summarizing the discussion of the work problem, we note that we have discussed the three historical approaches used to increase the amount of work needed for a given task:

(1) Use capital to purchase more workers.

(2) Work at strategies to increase productivity.

(3) Where applicable and economical, harness technology to do more work.

The discussion has shown that options (1) and (2) are not very feasible, whereas this is a propitious historical moment to work with option (3), the use of technology. Assuming that technology can be economically harnessed for education, then let us see how the additional work will help solve some of the central educational problems faced by an elementary school teacher. Turning to the four points in order, we note:

(1) The first task, the presentation of accurate material at an appropriate level for each student, is a very simple one for a computer which can readily retain norms on each student that are automatically updated after each instructional session. Thus whenever a student works with a device under computer control, he will automatically be receiving individualized instruction designed to fit his particular needs at that time. This will increase his learning productivity dramatically because he will no longer be sitting passively listening to presentations that are only partially relevant to his needs.

(2) The computer-driven instructional devices perform superbly in the second major task of the teacher, giving trials with appropriate feedback. As soon as the student responds, the computer generates an immediate response. Thus instead of having to wait to learn whether or not he is right, the student gets an answer while still actively engaged in the learning process. In a few minutes on a terminal a student can often receive more trials and responses than he would in a few weeks of formal instruction in a normal class. The immediacy of the response is important because it prevents false learning patterns from taking root. The trial-response sequence can also be designed to ensure that the student gets precisely the right sequence of information needed to learn the concepts most efficiently. Teachers often have a problem maintaining a sequence because class

discussions and interruptions can deflect the presentation. Thus computers can assume an individualized tutorial role that dramatically increases the ability of students having trials and feedback.

(3) A third area of responsibilities for teachers is providing the motivation and encouragement for students to work. Obviously the teacher will always be prominent because students will need the encouragement and example of adult models; nevertheless, some of the early research with computer terminals has unearthed some interesting motivational advantages they can offer, particularly in negative learning environments. Poor students enjoy very much working at a single station where they are able to learn at their own pace without the group evaluation and judgment of their performance. Other students enjoy the ability to work rapidly without being labeled a teacher's favorite. In Chicago one student was heard to exclaim that he enjoyed working with a terminal because it didn't know he was black. In Provo, Utah, some predelinquent learners expressed approval for another reason: they found that they could control the terminal instead of being controlled by the teacher. Although this does not sound like a very important point, for a population that is constantly on the fringes of trouble in a school system, the issue of control is a substantial one. The very fact that they alone were able to initiate the process, and that the computer never deviated in mood or patience, became very significant to these children.

Another dimension of the computer that heightens learning motivation is the addition of games that have educational application at strategic moments in the learning cycle. Every elementary school teacher is tormented by the knowledge that little boys who are unable to compute anything mathematically can discuss with great insight and passion the mathematical batting averages of all the leading hitters in the American and National Leagues.

(4) Not a great deal has been written about the fourth point, the issue of replication, because most teachers have a difficult enough time mastering one curriculum in a lifetime without being able to bear the responsibility of assimilating many new ones, much less becoming responsible for initiating other curricula and seeing that they are replicated effectively at other sites. Quite obviously the issue is not a popular one because the amount of work required to effect these replications is prohibitive. One of the most effective uses of the additional work that technology can generate, however, is the power of replication.

Probably the reason that replication is so difficult in a standard educational system is that most of the tasks that are to be replicated must be effected through a chain of human beings in sequence, that is, through an oral tradition passed on from person to person. If this chain can be avoided, then replication can be accomplished with

exponentially greater effectiveness. In the teaching profession, the invention of the book broke the back of the oral tradition problem in passing information out from human to human. It is important to note that not only is the passing of information from human to human a burdensome and almost impossible work task, but it also is a poor approach because each passage of the information allows errors to be introduced in the transmission. This currently is what happens to most curricula, although the book has been able to stabilize, to some extent, the ability of accurate information to be released in an untarnished state to a great many people. A diagram should help clarify this point:

Historical Overview

(A)		Teacher used to cover all four points: (1) Information, (2) Trials, (3) Motivation, (4) Replication
(B)		After 1500 and the first technological breakthrough: (1) Partially covered by book after student can read; (2), (3), (4) Teacher still responsible for these
(C)		After 1980 and the new technology: (1), (2), (3), (4) Will receive help in all of these

A central and critical point illustrated by this diagram will be the impact that technology will have on aiding innovation. As we have seen, the technology that produced the book has enabled innovative curricula to be printed and distributed. Unfortunately, as the discussion has shown, teaching requires more than accurate information in a book. The book's major weakness as an instructional device is its innate passivity. The teacher must provide the interactivity with the student in order to heighten the latest resources in a book. Thus although an innovative program can have books available to teachers and students with totally accurate information in them, the teachers must be trained through the oral tradition. Inevitably, then, something is lost between the original innovator and the young instructor who is told fourth-hand what the new program is.

Since computer programs contain a great deal of interactivity built into them, they are less dependent on teachers' being trained properly to provide interactivity with them and, more importantly, maintain the same precision of interactivity day in and day out without drifting away from the original vision of the program. Thus philosophically they ensure the accuracy of adequate interactivity, much as the printing press assured the accuracy of the original version of a book. And just as the printing press alleviated the problem of the oral tradition in storing and retaining accurate information, so the computer terminal will alleviate some of the problems of the oral tradition in training faculty to provide the proper instructional interactivity in new innovative programs.

Some training will be required in order to introduce successful innovation with computer materials, and this training will greatly add to their successful usage. But the critical point still remains that since the technology will carry within itself the ability to handle far more of the instructional process, as the above diagram illustrates, we can be certain that innovative curricula will be able to be distributed (replicated) at a certain guaranteed level of effectiveness.

In addition, the new technology will probably produce such a surplus of work potential that beyond handling the four teachers' tasks already discussed, there will be a number of new educational opportunities that will be able to be pursued. After some twenty years of pioneering by some great educators in trying to harness the potential of education for computers, some interesting additional opportunities are becoming clear:

(1) The introduction of simulations in a curriculum to allow a student to pursue the implications of decisions. Some common simulations are making the user the ruler of a nation, the president of a company, the mayor of a city, or a scientist doing experimental research where the variables are constantly changing, as in studies of pollution, photosynthesis, or a famous physics project.

(2) The introduction of a new language to students (a computer language) which will allow them to enter a brand new world of personal experience. As many scholars have indicated, using a computer language allows a student to work in a "discovery" mode where a complex amount of learning revolves

around the experience a student has in debugging his programs. The programs postulate a logical description of reality or a process that the student assumes, and his immediate testing of his logic by running the programs is extremely beneficial in teaching him about logical processes, including the cultivation of a healthy and open attitude toward the growth provided by the debugging process.

In addition, programs that harness the power of the computer can be extraordinarily useful and powerful, so the student frequently has an area where he can assert years before his classmates as they pursue alternate languages in the curriculum. This aspect of using the computer language seems particularly helpful for the brighter, disaffected students.

(3) From an advisor's point of view, the computer will be able to help give testing information on the students' abilities and progress. Most schools are currently handicapped in having enough information available about the student to give sensible advice on curriculum, college, and career choices.

(4) The computer will also offer many management helps to the teachers as they help to manage the students' progress through the curriculum. Computer managed instruction has been one of the most fertile of the early uses.

(5) One of the most interesting uses will follow from the computer's ability to keep records on a students' trials and progress. After some further research, teachers will be able to assume a new relationship with students that will enable them to help the students understand themselves as learners, that is, to understand their own learning profiles and styles. This type of information is always extremely useful because it has serious student management and career implications. Prior to the understanding and articulation of dyslexia, for example, many dyslectic young children were put into psychological analysis and therapy because parents thought their learning difficulties were emotional and not physiological impediments.

Obviously these are just a few of the types of opportunities that the additional work potential will provide. In a sense, determining how to use this potential will probably be the most exciting aspect of harnessing the new technology.

But the most challenging task, as always with technology, will be to ensure that it is not misused. This may be a difficult problem because the technology may be upon us before we are prepared. The failure of a false start in the 1960's left many critics with ample ammunition to discredit the pioneers, but this time around the technology will take because the culture will be flooded with it. The calculator was the tip of the iceberg. We may love horses, but this is 1905 in the automobile industry. We should heed the lessons we did not learn in preparing for the advent of the car.

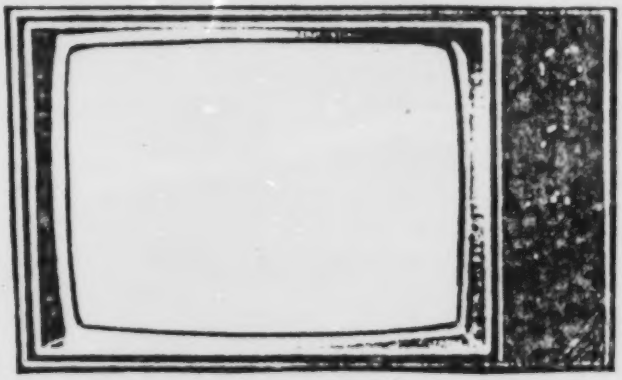
Summary

The first section of this paper has suggested that education has developed to a point of effectiveness which cannot be significantly increased by a very great percentage either through the addition of more capital, increasing teacher or student productivity, or through pursuing research and efficiency strategies. Unfortunately, the system has reached its limitations at a time when a great deal more must be required of it in order to ensure that the population being educated will receive sufficient skills to handle the types of jobs which will predominate in tomorrow's society.

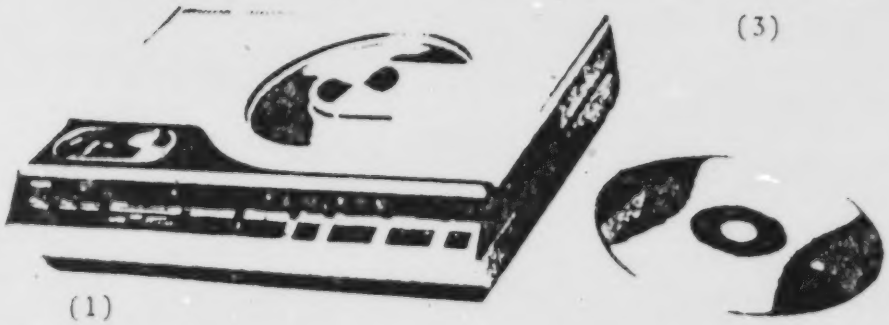
The central problem appears to be producing more work in order to ensure that the individual students are trained sufficiently. The analysis has indicated that a technological solution is probably the only way that the requisite amount of work can be obtained. For this reason for the next ten to twenty years the general thrust of educational research and development should be focused on harnessing and learning how to handle this new additional source of work.

II. THE VIDEODISC

In discussions of the videodisc, the reader should be aware that in the early, or consumer model, videodisc there are three components to the package: (1) a videodisc player, (2) the videodisc itself, and (3) a color television set connected by wires to the videodisc player:



(3)

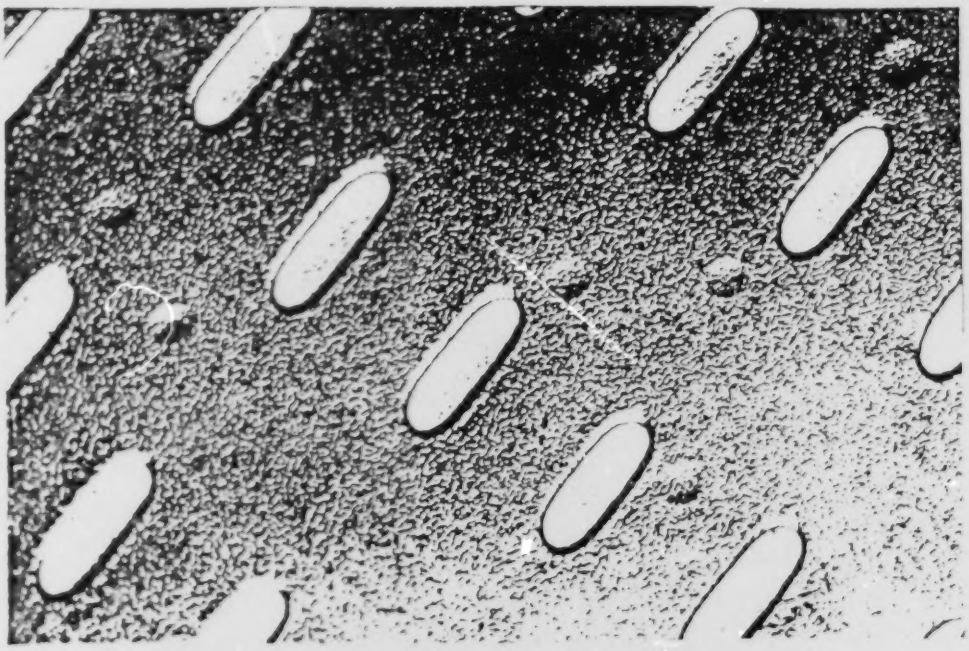


(1)

(2)

A short time after the consumer model is introduced, a microprocessor will be added as a fourth component to allow the player to be driven under computer instead of manual control. For the purpose of this paper the two systems will be distinguished by calling the first the consumer model and the second the educational model. Actually, both models will be usable for education, but the addition of the microprocessor will make the videodisc a much more powerful educational device.

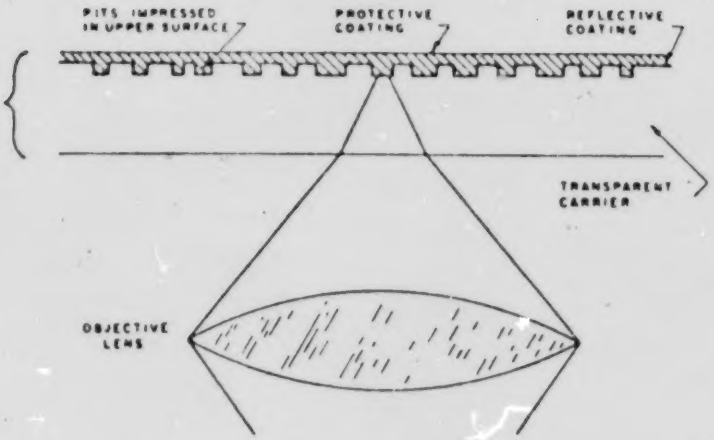
The videodisc looks very much like a shiny silver-colored LP record. Unlike the LP record, however, the videodisc has its information stored on it by burning tiny pits with a laser on a metal master, as the following diagram indicates:



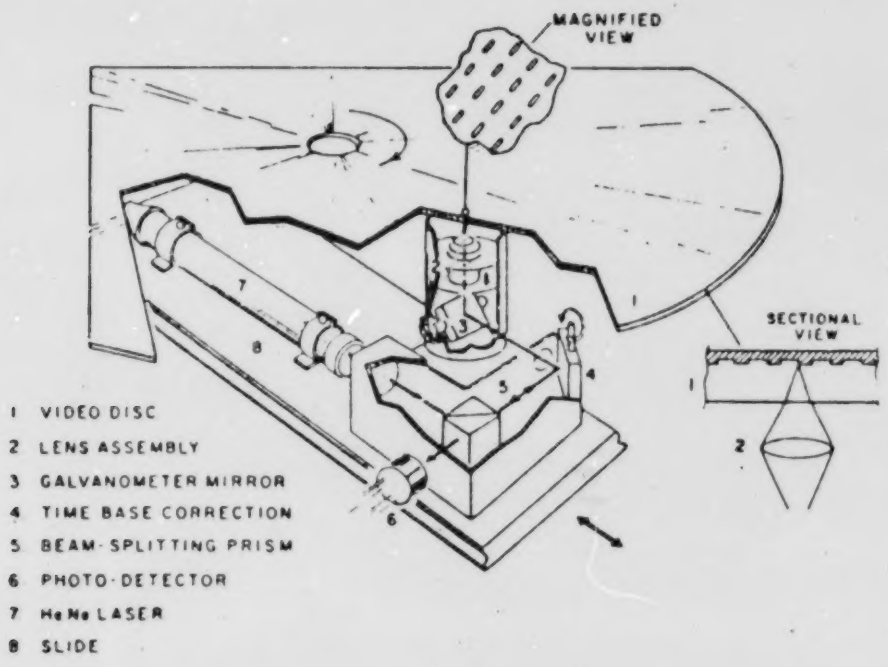
The density of the pits is quite extraordinary with approximately 650,000 of them being stored in an area the size of the head of a pin.

Then, following a procedure similar to that used to produce LP records, a nickel stamper copy is prepared from the master disc. Plastic discs are then replicated from the stamper and are given a reflective aluminum layer to enable them to be read more easily. Then a protective coating is placed on top of the videodisc and a protective transparent coating, which can carry light, is put on the bottom of the disc. A laser light, acting as an "optical stylus," reads the disc from below.

Cross-section of disc being read in a videodisc player



The following diagram is a portrayal of a videodisc being read by a laser:



The arrangement of the laser pits that carry the information in the videodisc is dictated by use of the device for a color television format. The pit information is stored in a series of tracks that have the following characteristics:

(1) Color television still frames (54,000). There are 54,000 tracks on the early versions of the videodisc, and each of these tracks contains enough information to generate one full color television frame. The way the figure was determined is as follows. In order to give a semblance of motion, color television frames are played at 30 per second, and since the design goals for the early discs are 30 minutes of television, the record has

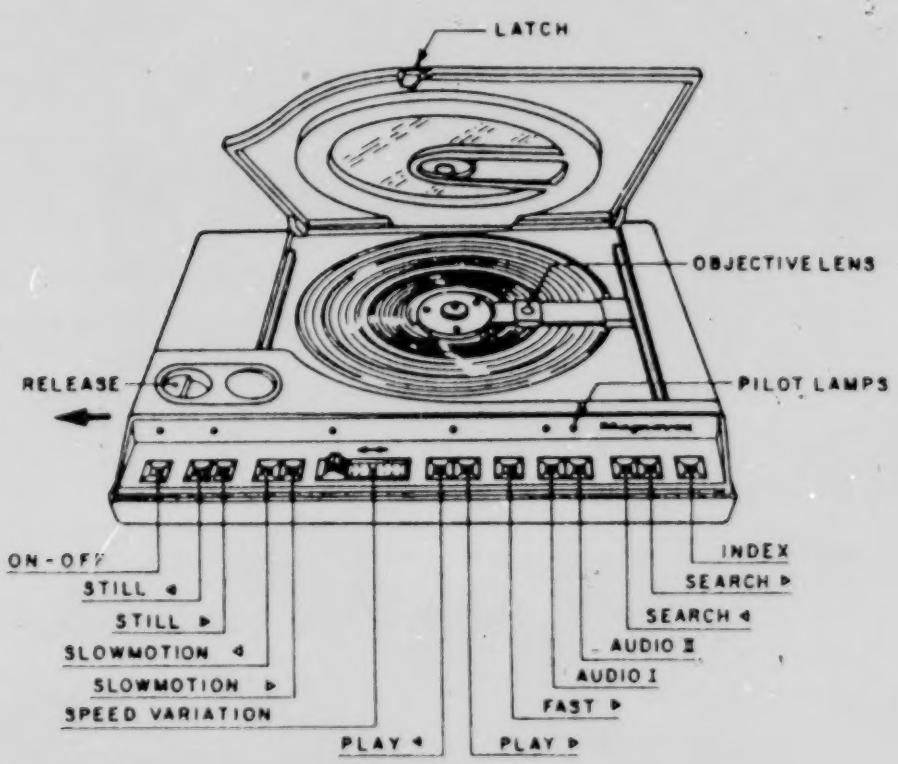
1 circular track for each color television frame
x 30 for each second = 30 tracks
x 60 for each minute = 1,800 tracks
x 30 for 30 minutes of playing time = 54,000 total tracks

(2) Sound (two channels). Also encoded in the pits of each track is sound information that allows two different sound channels to be stored. They can be played simultaneously to provide stereophonic sound, or one channel at a time. Because of synchronization problems the audio is silent when the record is being viewed in a still frame, slow motion, or reverse order sequence. Thus the audio only functions when the record is playing in a normal 30 frame-per-second forward motion sequence.

(3) Frame numbers (54,000). Also encoded in each track is the particular frame number of that track. When playing the videodisc, the user has the option of either displaying the number of the frame in the corner of the screen or omitting it. If the number is omitted, there is no hole in the screen, and the portion of the picture that has been overlaid by the number returns to the screen.

(4) Automatic stop devices. Information is also encoded on the disc which tells it when to automatically go into a still frame mode. As we shall see later, this can be a very useful educational device.

The player, as the diagram below indicates, looks like a record player with many additional controls on the front panel.



The triangles in the diagram next to the control labels point in the direction the control will be driving the disc read mechanism.

Videodisc information is read from the disc by shining a laser through an objective lens, where it comes in contact with the spinning disc and is reflected back through the objective lens, having been modulated by the aluminum coated pits on the underneath side of the disc. This modulated signal is amplified and sent to an unused channel of the color television set.

Two important points about the laser need emphasis:

(1) The objective lens focuses the light beam inside the transparent protective coating (carrier). The advantage of this inner focus technique is that dust particles, fingerprints, and scratches on the outside of the disc's protective coating will not be in the plane of focus, and hence the disc will have a long and accurate lifetime.

(2) Similarly, since the laser is acting as an "optical stylus," there is no physical wear as the disc is read. Thus, unlike an LP record, dust, fingerprints and scratches on numerous planes will not degrade the performance of the videodisc.

The controls in the above diagram are almost self explanatory:

(1) Still. Touching the Still control holds the current frame in a still position on the television screen. It accomplishes this by reading the same frame track 30 times a second.

(2) Slow motion runs the disc at the speed set by the Speed Variation control at some rate "between" the Still frame position and the Play (normal speed) setting.

(3) Fast allows a 3-times normal forward speed to be applied.

(4) Audio I and II allow for a choice of the audio channels.

(5) Search allows a rapid search of the disc in either direction.

(6) The Index key either displays the frame number or omits it.

Some Educational Implications of the Characteristics of the Videodisc and Videodisc Player

The physical characteristics and capabilities have some interesting educational implications:

(1) Automatic frame stop. The normal color motion picture presentation will have an important instructional feature added by this ability. After an instructional sequence using motion pictures, the disc will freeze on a frame that begins a formal instructional sequence which requires response from the student.

(2) Frame numbers. Because each frame has a code number, or address, the students will be able to branch rapidly to find specific information. In the consumer model this will be done manually, but when the educational model appears with a microprocessors, this address becomes critically important since it will allow for automatic interactive instruction. If a student responds to a question improperly, the computer will not only process his answer, but will be

able to go automatically to a preassigned frame number that will begin a proper sequence of instruction as feedback to the student answer.

(3) Dual audio tracks. The audio capabilities will allow the student to listen audio in one of three ways:

(a) in stereo, or

(b) in any one of two languages, or

(c) in an elementary or advanced version in his native tongue.

Thus the student might view the material first in English and then a second time in Spanish, or he might hear an elementary description first, and then view the same material while listening to a more advanced and complex description. One version could be for a layman and the other for a scientist. Publishers might use the same visual material and reserve one sound track for high school students and the other for a presentation for advanced college students.

(4) Adjustable forward and reverse timing. Slow motion (timing) sequences will be used by students who want to follow the motion continuity of the materials they are viewing at a pace they can comprehend. There are some other interesting possible uses of this timing mechanism, however, because the same timing device could also be useful for building timing and pacing potential into instruction. Some classes, such as reading, might want to pace students in their exercises.

Another obvious subject matter area that could use a pacing device would be a typing class.

(5) Manual fast forward and reverse search. At first glance these controls seem like a utilitarian necessity, but a close analysis of the potential they produce suggests some important instructional implications. The fast forward and reverse feature will encourage the student to search through the disc in a discovery mode. The appeal, and hence motivation, that this feature carries with it is most impressive. A visual color motion presentation with sound is inherently the most interesting to view, but never before has a viewer been able to race through the material and pause, by choice, to assimilate or review sections of interest. After using this feature for a few moments, a user discovers:

(a) The excitement of visually exploring the unknown in color, sound and motion.

(b) The pleasure of being able to skim past the unwanted. Viewers traditionally are held hostages to time when viewing movies or television, and the videodisc emancipates them from this burden.

(c) The speed with which the materials can be viewed. This speed of traversing the disc should create an enormous market for new materials.

(6) Still frame. Conversely, the still frame device will lead to a much more profound depth of learning than television

or movies currently allow because this characteristic encourages the viewer to focus and dwell on discrete units. Obviously, freezing a single frame from a motion sequence allows a more careful look at a detail, but the real significance of the still frame will follow from its ability to allow supplementary material to be added to the motion sequences in graphic and textual formats.

The addition of these graphic and text slides is significant because they allow an extraordinary in-depth treatment to be made for any subject that has been portrayed during the motion sequence. In ten seconds of viewing time of a motion picture, a commentator cannot describe a great deal to the viewer. Those same ten seconds can support 300 individually different slides full of specially constructed graphics and prose materials to lead the viewer through a complex learning experience which describes in great detail the implications of what the viewer has seen during the motion sequence.

One of the interesting lessons the still frame device is teaching the first authoring teams about the motion picture sequence is how inherently poor an instructional device a motion picture can be. A picture may be worth a thousand words, but there is no way for a commentator to offer even a fraction of the information the viewer needs to understand

what he is viewing to any profound degree. In fact, motion picture and television technology have provided an extremely unbalanced teaching mechanism. Visual material has stunning import and potential, but because of the time restrictions, the verbal commentary tends to be extremely superficial.

Another way of describing the contribution of the still frame capability is to say that it will allow a motion picture sequence to have thousands of pages of interactive textual material and graphics to be added to it. In fact, as the authors design and write the individual frames to complement the powerful motion picture sequences, they comment that they feel as if they are writing chapters of a book around various motion picture sequences.

(7) Chapter stop. The chapter stop is a fast forward or reverse tab key that goes rapidly to predesignated locations in the videodisc that may be thought of as chapters. Obviously such a capability will allow an index to be used to help move a reader about the disc with great efficiency. But it will also encourage the use of glossaries, minor dictionaries, and reference sections. Thus some features of the book will be added to the disc.

(8) Adding audio capabilities to still frame formats. After the development of the consumer manual model, and the subsequent construction of the educational model with the

microprocessor, a third logical evolutionary capability will probably involve the addition of audio capabilities with still frame formats. If the information stored by the pits in the tracks is reserved for audio alone instead of also including the television information, then each track of the videodisc could store about 10 seconds of speech. One way of using this capability might be to reserve an audio track after each still frame where 10 seconds of speech would be useful. Pushed to its maximum in using this strategy (reserving every other track for audio), the capacity of the disc would drop to 27,000 still frames, but would now include 75 hours of audio that could be played during still frame presentations. Such a disc could mix regular motion picture presentations with the still frame commentary. One obvious use of such a disc would be to have a talking encyclopedia presentation.

Ultimately, authors will view the videodisc's capabilities as a series of options that they will use in terms of their particular instructional needs. The basic unit will be the individual track which will be used in one of three ways in relation to different time requirements:

(a) In a normal motion picture sequence with audio where 30 frames (tracks) per second will be used.

(b) In a still frame mode where any one of 54,000 frames (tracks) can be addressed and held in a frozen position for as long as desired.

(c) In a still frame audio mode where tracks will be sacrificed to give audio capabilities to still frame presentations at the rate of 10 seconds of audio per track.

(9) The use of movies and television tapes that have already been developed. There is an enormous body of tapes and movies previously developed for education or with educational potential. By adding interactive instructional frames to these materials, educators will be able to draw upon millions of dollars' worth of materials that have already been produced. Publishers will be able to upgrade instructional movies, television networks will be able to draw on their existing materials (including videotape news presentations), and commercial filmmakers will be able to offer some of theirs.

(10) Productivity. Perhaps the most impressive contribution of the videodisc as it is coupled with the microprocessor will be its dramatic increase in learning productivity (the productivity of the learner instead of the teacher). In the first section of the paper this point was touched on, but the point is so important that it needs amplification. Using a videodisc with an interactive keyboard, the student's productivity will soar because:

(a) He can interact with the material at a time of his own choosing. He will be able to go to those sections of the material which he chooses to work with at that

moment, and if he has problems he will be able to review the materials with excellent interactive instruction. The material that is presented to him will be exactly at the appropriate level for his individual needs, and should he choose he can explore aspects of it in great depth. As he does interact with the material he will have numerous trials at mastering it with immediate feedback as to how he is doing with each trial.

(b) As we move beyond the domain of the young learner, the videodisc will save enormous amounts of travel time for the adults who must now commute to centers of learning with the attendant cost in time, money and energy.

(c) The videodisc will also help employees get on-the-job training without having to drop out of the work force for protracted periods at distant company training sites. An interactive videodisc station could exhaust a learner with one to two hours of daily training that would require just a portion of the working day. Thus the learner could basically stay on the job while still receiving excellent training with a minimum of productive and social disruptions.

(d) Another productive use of the videodisc will be its use by workers and students to help refresh them and retain the skills that they have just mastered in previous training. Frequently an enormous investment in time and finance is required to train someone, and then when

he goes back to the work force or ends a semester he quickly begins to lose the knowledge he has mastered. Short interactive sessions with the videodisc will be an excellent way to help the learner retain, and indeed enhance, the original learning experience.

(e) The videodisc stations will also be an excellent way for the professional work force in any category from sales to military or medical personnel to receive instruction updating their skill or knowledge areas.

The Videodisc in Perspective

The educational potential of the videodisc can be heightened by comparing the videodisc to other technologies. The three most important technologies that education has attempted to harness are:

(1) The book.

(2) The motion picture (television).

(3) The computer.

Each of these technologies has enormous strengths and weaknesses as an educational device, and before we examine the videodisc in relation to them we must see them in perspective.

The book. Most people have forgotten that the book is a product of technology, and indeed to date is by far the most successful use of technology in aiding education. It is portable, relatively inexpensive, and has random access abilities. It can be easily replicated accurately and distributed. There are some major disadvantages of the book, however:

(a) It is not interactive.

(b) It lacks motion and sound.

(c) It cannot be personalized or modified very easily.

(d) It produces only fair learner productivity because of the first three points. The book is inherently a passive device which requires a well trained, highly literate and highly motivated user to be effective. Unfortunately, the population that needs to be trained the most is functionally illiterate and, therefore, has difficulty using the book.

Television (the motion picture) once appeared to have the greatest potential of any of the media for instruction. It has many obvious advantages including the expense of the equipment, the lack of communications costs, and the fact tnat it is already present in almost every home. After a number of years of usage, however, there are some fundamental shortcomings in the use of television broadcasting as an instructional technology. While the technology increased the productivity of the teacher, it is not a very productive approach for the learner. Some of the shortcomings from the productivity of the learner are as follows:

(a) He must arrange his time to be available at the moment the material is being broadcast.

(b) The presentation is in a serial form so that he must wait patiently for the appropriate significant moments. Even in reading a newspaper one has random access ability that television lacks.

(c) He cannot stop the material and review it if he has suddenly found it too difficult.

(d) The materials being presented rarely are at the appropriate level for his individual needs at that point. He cannot have an easier or harder version of what he is studying, and he cannot go into any aspect of it in any depth.

(e) He cannot interact with the materials and get a response as he attempts learning trials.

The strengths of a standard computer assisted instruction approach with either CRT or teletype terminals are well known. Instruction can be individualized and made highly interactive. There have been some graphics materials added with special graphics terminals, but for the most part the standard CAI approaches lack the ability to use the motion picture sound and color format that can be so appealing to a student. To date these systems have been expensive and also require high communications costs when the materials are placed at a distance from the host computer.

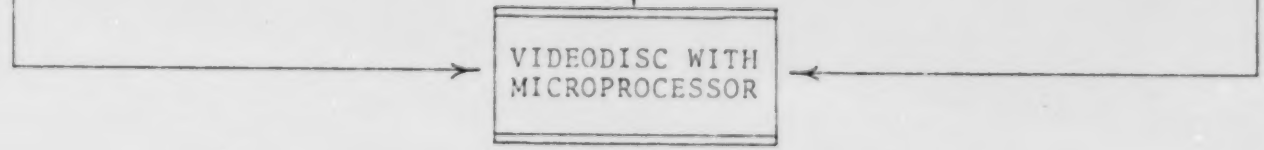
The Videodisc: A Combination of Strengths

The single most important insight to retain about the videodisc in education is that it combines the strengths of these three previous technologies. Since it combines these strengths it helps eradicate their weaknesses because, as we have seen, each technology's strengths complement the others' weaknesses. A chart should help to clarify this:

BOOK	
Strengths	Weaknesses
1) Random access. 2) Inexpensive. 3) Availability. 4) Replicability.	1) No interactivity. 2) Lack of motion & sound.
Fair Learner Productivity Fair Presentation Format	

TELEVISION (MOVIES)	
Strengths	Weaknesses
1) Audio capability. 2) Visual format allowing photography. 3) Motion capabilities. 4) Use of plot & characterization. 5) Ease of availability.	1) Serial presentation, no random access ability. 2) Inability to freeze a frame. 3) Inability to give trials with feedback. 4) Passive system. User cannot initiate any materials.
Poor Learner Productivity Excellent Presentation Format	

COMPUTER	
Strengths	Weaknesses
1) Random access ability. 2) Ability to give trials with feedback. 3) Active system. Ability to compute & run programs.	1) Lack of audio. 2) Poor presentation format; primarily black & white. 3) Lack of motion & photography. 4) Lack of characterization & plot abilities. 5) Expense.
Poor Presentation Format Excellent Learner Productivity	



(STRENGTHS OF ALL THREE TRADITIONS)

As the chart indicates, the videodisc combines the strengths of the other technologies. But the videodisc as a technology, however, has two potential weaknesses:

(1) It is a ROM (Read Only Memory), like an LP record, that cannot be modified by the user. Unquestionably many consumers will prefer a tape cassette unit which will enable them to tape any program they desire for just the cost of that tape. The videodisc cannot be modified by the consumer, and thus enough exciting material must be developed independently of standard television fare and kept at a low enough cost to make the player attractive for the consumer.

Even this apparent weakness has a positive aspect to it, however, because a Read Only Memory offers some protection from piracy for the commercial developers of educational and entertainment materials. Many of these commercial producers are reluctant to use a device such as a videotape cassette as a storage medium for their materials because they can be readily copied and pirated without paying royalties or purchasing additional copies from them. As we have already discussed, the format of the videodisc will most likely have motion picture sections alternating with many still frames, and any taped copy of this for a videotape player would only present fragmented movie clips followed by a blur of jumbled still frames

going by the screen at 30 frames per second. Even in cases where videodiscs have very few still frames in them, the tape cost for the copy may very likely be more than the cost of purchasing another videodisc.

(2) It is an unproven technology that must be sold in sufficient volume in the marketplace to keep its cost at a reasonable level. During the next few years there will be an interesting marketing struggle between the cartridge tape and videodisc manufacturers. The manufacturers of the tape players hope to place their products in great volume in the home market before the videodisc player manufacturers can complete their market testing and bring their product to the marketplace for the consumer. Their hope is that if the consumer is only going to purchase one playing device to attach to his color television set and if the tape cassette player is available sooner, they will wrest away most of the available market. In truth, since each device has unique abilities, both will probably find a niche in the consumer marketplace over the next few years.

The tape cassettes have one distinct advantage and five serious disadvantages in relation to the videodisc. The advantage is that the consumer can tape any program he wants from the television screen and retain a copy for his files. The videodisc must be pressed at a factory, so the consumer will only be able to play program materials that he has specifically purchased in videodisc form.

The disadvantages of the tape cassette approach are:

(a) The tape system cannot currently be accessed randomly, and although there will undoubtedly be some attempts to rectify this in the future, it will always lack the simplicity, speed, and reliability of the videodisc technology.

(b) The cost for the tape itself will exceed the cost of the videodisc materials. Thus the videodisc should always cost less in raw materials to manufacture than tape cassettes.

(c) The mechanics of handling tape are inherently more complex than those of handling the videodisc. This means that the equipment will have to be more complex and will have more reliability problems.

(d) The tape will always wear out after extensive usage, whereas the videodisc, using a laser stylus, will for all practical purposes last indefinitely.

(e) Unless unusually high volume is achieved, the price of the tape player will also be more than the videodisc player because of the equipment's complexity.

A discussion of costs in developing educational materials will be found in the next section on authoring. At this juncture we can make some reasonable guesses that will serve as general guides:

(1) The videodisc consumer model player will sell in the neighborhood of $500.

(2) The cost of the material used to press a videodisc will probably be in the 20¢ to 50¢ range.

(3) The records are likely to sell commercially in the $10 to $20 range per set, although it is conceivable that the cost could drop as low as $5 for some markets. A two-hour movie would require four discs, and the movie would be sold as a set.

(4) The more sturdily built educational model with the microprocessor will probably retail in the $1,000 range.

Summary

Each of the technologies has special strengths and weaknesses, but overall the videodisc should have the ability to combine the best features of a number of the others. The hardware will be inexpensive and yet, while retaining the emotional impact of motion and sound inherent in a film or television medium, it will also add the ability to offer individualized and interactive instruction for the students that has been available only with computer assisted instruction. For a more complete discussion of various educational technologies, please see Appendix A, entitled "A Brief Discussion of the Strengths and Weaknesses of Various Educational Technologies."

III. AUTHORING FOR THE VIDEODISC

Generally speaking, authoring for the videodisc involves two separate and distinct production modes that stem from entirely different educational traditions:

(1) The motion picture tradition that includes movies and television. This tradition usually requires expensive production facilities; carefully scripting; attention to plot, character, and setting; and derives its power from its strong color, motion and sound content that simultaneously affects many of the viewer's senses.

(2) The production of still frame slides. This tradition derives its strength equally from its textual and graphic mix. From an authoring standpoint, the planning and writing of the individual frames, which constitute an instructional unit, approximates the writing of chapters in a textbook. Graphics specialists are needed to add color and graphic capabilities.

Since these two traditions are quite different, early authoring efforts should probably avoid extensive motion picture or television production and concentrate initially on modifying existing film or television materials while the team learns to write educationally sound still frame materials. On the surface, the production of still frames appears to be a simple task in relation to the production of a film or television project. But in truth, the production of sound instructional materials using the still frame capabilities of the videodisc is a very complex process. Fortunately, the TICCIT project

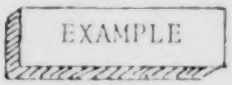
(Time-shared Interactive Computer Controlled Information Television) recently completed a multi-million-dollar, multi-year project whose central focus was the development of learning strategies to produce still frames which would allow excellent interactive instruction with a color television set.

The TICCIT Approach

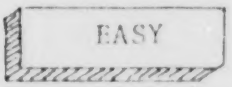
Two fundamental contributions that the TICCIT project offers are:

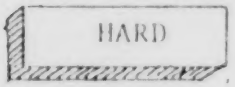
(1) The use of a sound learning theory which encourages the production of effective instructional materials. The instructional scientists who designed the TICCIT learning theory produced a keyboard constructed around special learning components which are represented by different keys. Some of the keys are:

The RULE key gives the student the generalization, concept, rule, or law that he will be learning.

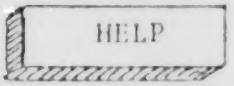


The EXAMPLE key gives the student an example or particular case of the generalization or rule that has been previously expressed.

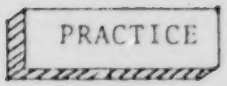




The student can go back and forth between the rule and many examples, and by pressing either the EASY or HARD key, can receive an easier or harder version.

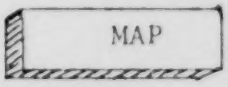


If a student is totally confused, he can hit the HELP key, which would give him the most simple and basic information about his task.

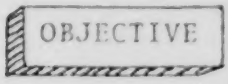


The PRACTICE key generates problems for the student to work with in order to practice the concept that he has theoretically learned. After the student attempts to answer the practice problem, there is feedback given on his response.

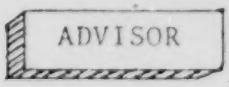
(2) The use of special orientation keys to help a student maintain a clear vision of his goals, progress, and personal learning style. Some of these keys are:



The MAP key offers the student a menu of what is available while simultaneously suggesting prerequisites and orienting him as to the status of his current progress.



The OBJECTIVE key gives the student a clear explanation of what he is expected to learn in the coming lesson.



The ADVISOR key is used to give the student orientation on his current progress and advice on the merits of his particular learning strategy that the computer has tracked.

In the original TICCIT project the keys were under computer control, so the individual frames were generated on the screen automatically in response to the student's touching the key. The first videodisc models will lack this computer control, but the features which were painstakingly worked out in the TICCIT project will re-surface when the microprocessor features are added. In

the interim, the TICCIT taxonomy (or vocabulary) is a good one to work with to the extent that the features fit the videodisc.

The most obvious learning component keys that would be useful are RULE, EXAMPLE, PRACTICE, HELP, MAP, and ADVISOR. Initially the consumer model will lack a keyboard, but these features can and should be included in the still frame design. In developing the individual still color frames, the TICCIT instructional scientists learned to label each slide so that the student would be oriented as he viewed the material. Thus in the bottom of the frame, the word RULE, PRACTICE, EXAMPLE, etc., would appear. Since the student would go through the still frames one by one, just as he will with the videodisc, another label was added to tell him which page of the explanation he was on. Thus a frame might say on the bottom RULE, PAGE 2 OF 5. This would tell the student that he was viewing the second of five still frames which were explaining that particular rule. When applicable, the still frames would also include the word EASY or HARD to orient the student to the degree of difficulty the strill frame represented.

Summarizing this point, the TICCIT project has shown that the authoring team should label its still frames in such a fashion that the student recognizes the learning component he is working with (i.e., RULE, EXAMPLE, PRACTICE, HELP, etc.) and is oriented to know where he is in his lesson sequence (i.e., PAGE 2 OF 6, EASY, MAP, etc.). These labels should be appended to the still frames in the consumer model even though the student will be stepping through the material manually. Whether the material is accessed manually or by

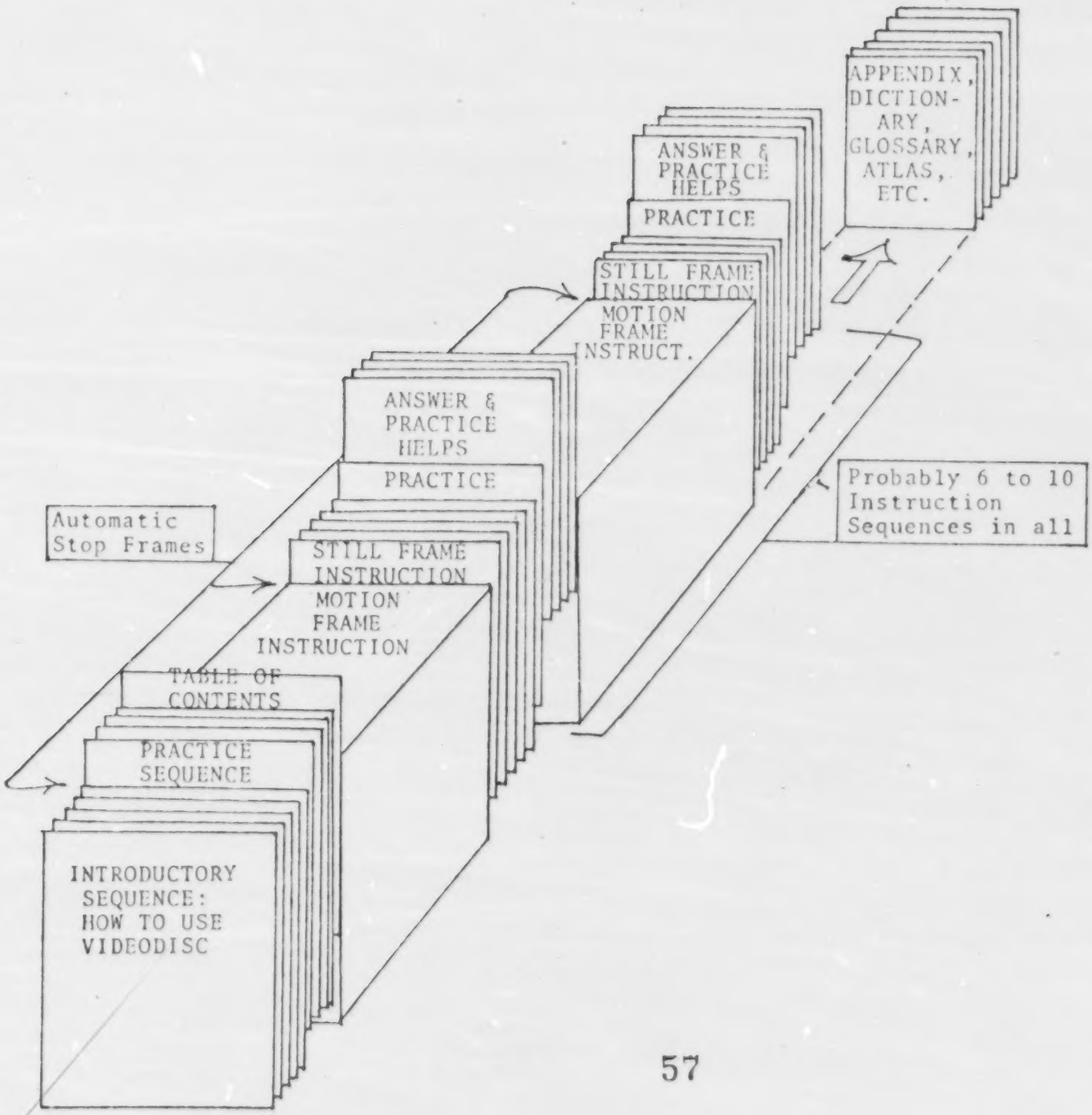
a computer, the instructional sequence will be approximately the same, and will have the same validity.

In addition, there is a second critical reason that the learning component and orientation features are used by authors in still frame production. Experience has shown that using this instructional vocabulary encourages the authors of the material to follow sound instructional principles in designing the materials. The very framework of the taxonomy or vocabulary inherent in the design places a structure over the production of the materials. In other words, authors are forced to define the rule, concept or generalization they are attempting to teach, and then to offer clear examples of it with carefully prepared practice items that will further clarify the concepts. Thus using the TICCIT model offers powerful instructional advantages that new authoring teams would do well to emulate. Unquestionably, in the future there will be many variations of the TICCIT model, but the project has made a profound contribution that should be assimilated before sophisticated variations are attempted.

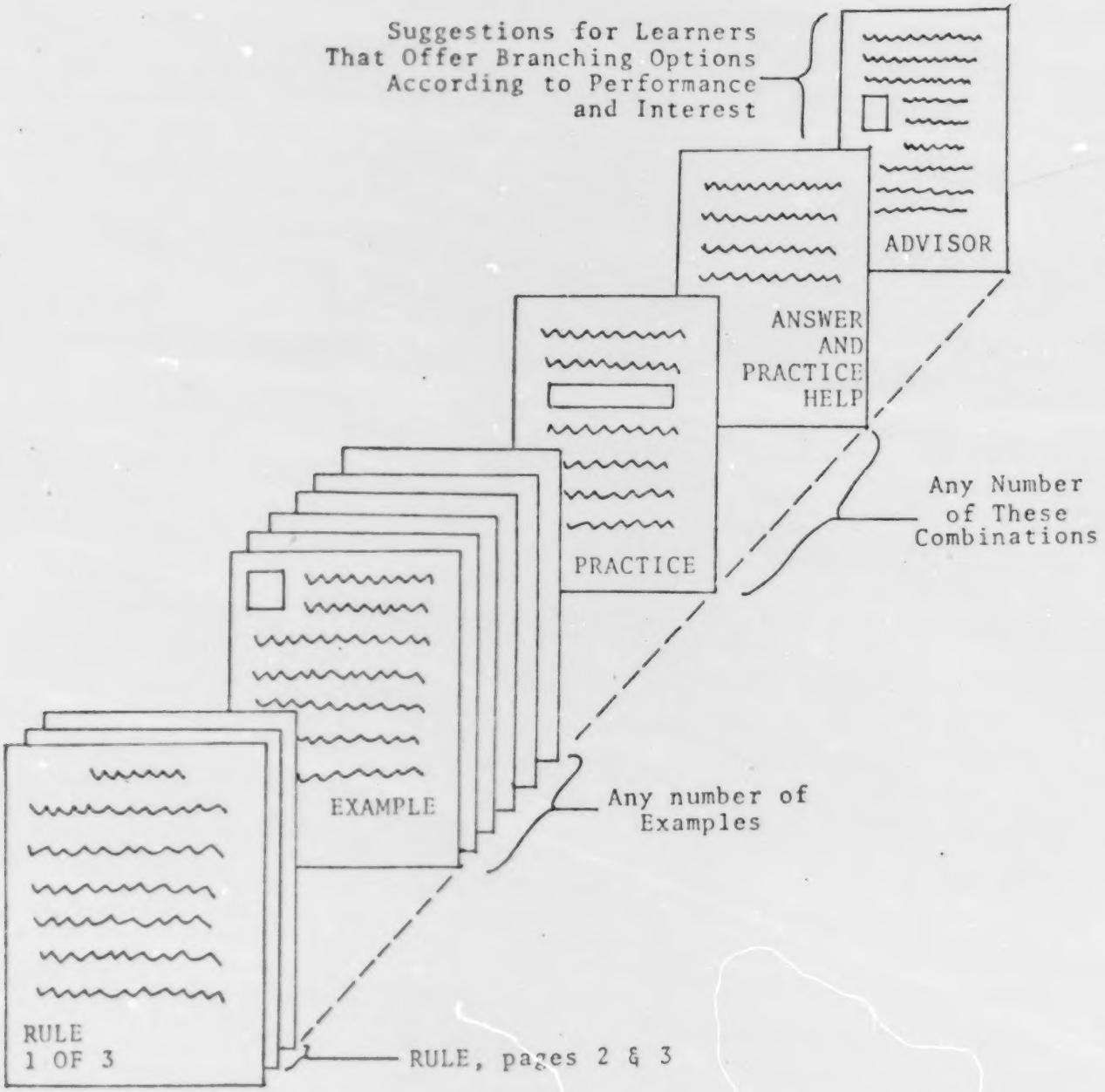
Schematic of Potential Videodisc Layout

A visual schematic should help represent the type of instructional flow that the videodisc will contain:

Potential Videodisc Layout



Closeup of Potential Still Frame Instructional Sequence



Authoring an Entirely Original Videodisc

Once a team has mastered the still frame process, a second logical project is the design of a videodisc that includes the production of original motion sequences as well as still frames. An interesting aspect of such an original design project is that since its requirements entail the production of moving pictures and carefully constructed graphic and textual still frames, once the project is completed the producer has substantially finished the tasks required to author some additional instructional materials. Thus the publisher of an original videodisc may be able to generate a broad array of instructional materials simultaneously:

(1) A videodisc.

(2) A 28-minute version of a movie for television.

(3) A 15-minute movie version for the school market.

(4) A slide tape presentation.

(5) A videotape version for VTR (videotape recorder) units.

(6) A workbook or laboratory manual.

(7) A full textbook.

(8) A computer assisted program that would give drill and practice for rote memory items from the material as well as simulations and games to buttress key concepts.

Having a broad array of products from one authoring effort may substantially increase the chances of a profitable return on investment, thus diminishing the risks inherent in financing the project.

Some Tasks and Components Involved in the Authoring Process

Generally speaking, there are four tasks involved in producing a videodisc:

(1) The creation or modification of materials.

(2) The scheduling and direction of the project personnel.

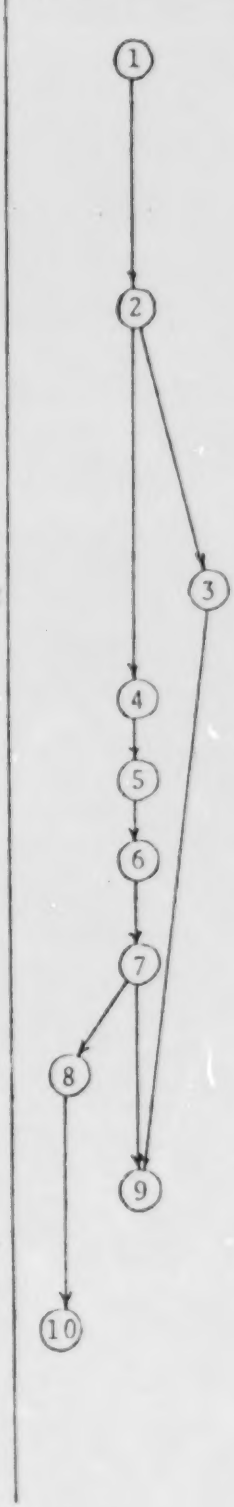
(3) The development and implementation of an instructional and evaluation strategy.

(4) The fabrication of the deliverables, particularly the master film or tape.

Stated another way, there are materials which must be developed by a production team, such as motion picture footage, audio tracks, still frames, and textual materials, that are designed to fit the team's instructional strategy, and these must be bundled into a deliverable package which includes such items as a master film or tape, student evaluation packets, etc.

Managing the team effort is a critically important process in a project that includes so many diverse elements. In order to help clarify the management task, we are including a document which diagrams a suggested set of procedures.

Procedures for Producing an Interactive Videodisc. These procedures assume a typical project that entails modifying a 20-minute 16mm movie for videodisc instruction by inserting still frames at appropriate points with appropriate branching instructional techniques.

TASKS	CRITICAL PATH	PRODUCTS
1) Plan new films or review old ones with subject matter expert to determine goals & objectives. Develop post-test.		Goals & objectives. Post-test.
2) Determine how film will be broken into divisions, & review other films for useful clips. Write detailed specifications for: Introductory sequence Glossary Each still frame question set with appropriate feedback frames Student response worksheets (if any)		Instructional specifications.
3) Write detailed specifications for mastering process, including chapter & stop frame codes.		Mastering production specifications.
4) Write required manuscript material according to the specifications.		Manuscripts.
5) Review overall specifications & manuscripts.		
6) Produce displays & photograph on 35mm or 16mm film.		16 or 35mm frames.
7) Test materials by presenting manual versions to students. Rewrite & change as necessary.		Revised materials.
8) Develop an interest questionnaire, alternate test & set of evaluation procedures.		Evaluation materials.
9) Splice 16mm frames into existing 16mm film. Proof carefully, edit final & send with mastering specifications. Print response worksheets.		Film to master. Printed text.
10) Prepare final report on costs, procedures, etc. Finalize procedures on administration & evaluation & attach response worksheets, post-tests, & interest questionnaire.		Final report. User packet.

A Detailed Description of Project Tasks

Task 1 involves working with the subject matter experts from the discipline portrayed in the film. They will establish learning goals and objectives and prepare post-tests based on those criteria.

In Task 2 the subject matter experts will then divide the film's content into logical learning segments and will decide at what point the discs will automatically stop and begin the individual still frame presentation. They will also review other related films for possible useful segments. After the film has been divided into logical learning divisions, the subject matter experts, in conjunction with the design scientists responsible for the project, will write detailed specifications for:

(A) The introductory sequence, which will appear at the beginning of the videodisc and is designed to help the student learn to use the particular interactive features of the disc. For example, it will show the student how to single frame forward or backward, how to use random access, the slow motion control, and the orientation description. Since each still frame will have some printed descriptive material on it to explain its purpose, the students will also have to be trained to understand this orientation feature. The introductory sequence will also explain the nature and purpose of any automatic stops used on the disc as well as the proper method of taking instruction and following the branching sequences of the still frames.

(B) A glossary if one will be used.

(C) The question and answer frames.

(D) The student response worksheets, if any are planned.

Task 3 involves the team member who is responsible for writing the technical specifications for the mastering process. He will be responsible for understanding the proper use of chapter and stop frame codes. He will also have the responsibility of making certain that the frames are counted properly so that branching frames in the final videodisc which instruct a student to go to some five-digit frame number will have accurate information. At this time he should also make provisions for obtaining as clean an original print as possible of the film as well as a separate audio track for the organization that will make the master tape.

In Task 4 the manuscripts must be written in accordance with the specifications that have already been generated.

Task 5. A review should be held at this point between the production team that has written the specifications and manuscript material and the organization that has commissioned the project. The subject matter experts at this point will recheck to be certain that the manuscript material is accurate in terms of its content. The instructional or design scientists will survey it to be certain that it is well designed and qualified personnel will survey the material in terms of its artistic merit and compatibility with the rest of the production.

Task 6. Graphics specialists are then called upon to produce the display which will then be photographed on 35 or 16mm film.

Care must be taken here not to display too much material in a still frame lest the presentation either be unclear or cut off at the edges by the television screen.

Task 7. A "simulation" of the interactive videodisc will then be presented to members of the authoring team, including the authors, instructional scientists, and technicians. Obvious errors or inadequacies should be identified by members of the team and the necessary changes made.

At this point these materials should then be presented manually to some students for their response. Then the materials should be re-written and changed as necessary.

In Task 8 the materials for an evaluation kit are developed. These include an alternate form of the post-test, a student interest questionnaire, and procedures for a later evaluation.

Task 9 involved the production of the final 16mm film which is the major deliverable product of the project. The film should be proofed very carefully and sent with an accurate set of mastering specifications that includes such information as which is the first frame of the film that starts the frame count, where frame stop and chapter stop pulses should be placed, and where the audio should begin. After the film has been sent to be mastered, the student response worksheets, tests, and other textual material should go to the printer.

Task 10. The user evaluation package should be put together and plans finalized for its administration. A final report should be written which documents the labor and costs involved in the

project. If the contracting organization so desires, the group that prepared the disc and evaluation packet can then follow through and administrate the evaluation, but this is not necessarily an authoring task. The feedback from any evaluation projects should help modify subsequent authoring projects.

Calculating the Labor and Time Requirements

In order to aid in estimating the labor requirements in terms of man-days, a "labor requirement chart" is appended. Following this is a suggested model for a time phasing chart that offers a reasonably accurate estimate of the amount of time required to modify a 20-minute classroom film for the videodisc.

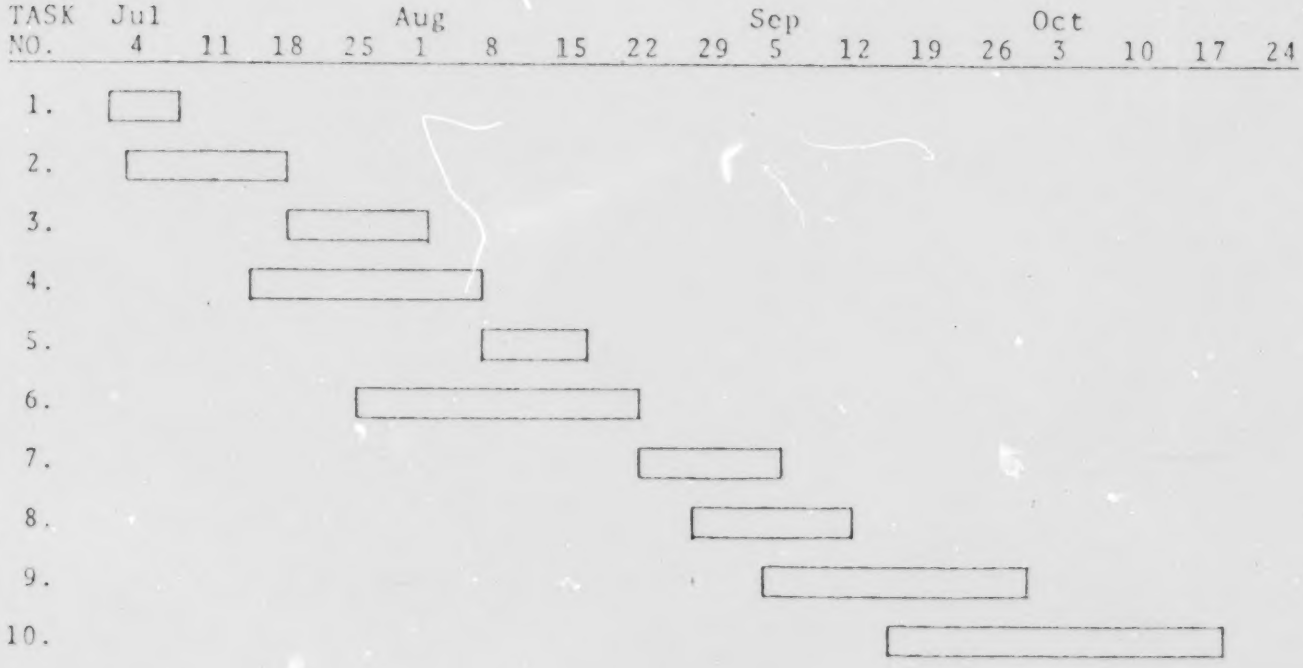
Labor Requirements Chart

Portrayed below is a possible chart to aid in the planning of personnel time to complete the project. The ten tasks relate to those already specified, and the list of personnel in the left-hand column is intended to suggest the types of people that would be required. In an actual project, the names of the personnel would be listed here. In the far right column under "Total Man-Days" there have been no totals listed, but these would all be filled in during the course of preparing for the project.

	TASKS										
PERSONNEL	1	2	3	4	5	6	7	8	9	10	TOTAL MAN-DAYS
Supervisory Time of Institution Leadership											
Project Director											
Design Scientists											
Subject Matter Experts											
Mastering											
Graphics											
Art Work											
Camera											
Typing											
					TOTAL PROJECT MAN-DAYS						

Time Phasing Chart

The chart below is a useful device to indicate time phasing for the project and help keep the project members on schedule. This imaginary chart was drawn up assuming a July 1st start of a project for the 1977 calendar year that would modify a 20-minute classroom film for a videodisc by inserting still frames at appropriate instructional intervals.



The Mastering Problem

The production team has the choice of making the master on a film or videotape. Unfortunately, since a great many still frames will have to be inserted amidst the motion picture material, the production team faces a difficult task in assembling the master film or tape which will be sent out to be stamped. The reason for this is that motion picture and television technology has developed around a moving film base, and so has the editing equipment. The

editing technology has been designed primarily to edit sections of film or tape, and not still frames. Furthermore, since magnetic tape requires motion as it goes by a fixed head to either receive or transfer out information, placing a succession of different individual still frames on such a tape is a very complex operation.

If the production team has access to a sophisticated television editing center, then it is possible to produce an excellent tape through the support of some specialized, expensive machines that such a center would have in order to sustain advanced television editing requirements. Two of these machines are:

(1) A special machine that can generate graphic frames with special character sets for tape. This machine is not a necessity because it is possible for the production team to use graphic specialists to hand-design and letter the hundreds of still frames that would be needed for an instructional videodisc. A 35mm camera would then be used to photograph the hand-produced graphics, and it is possible to read these 35mm frames in one at a time to the moving television tape. Obviously, a machine that automatically can make the best majority of the graphic slides is preferable.

(2) A computer controlled editing machine with a disc that can store and arrange digitally the individual tape frames on the disc in any order and hold them in a freeze frame position for checking. This disc is important

because normal tape machines, even under computer control, cannot easily move single frames from one tape to another because both the sending and receiving tapes have to be synchronized so that the single frame can be pulled from the one and installed in the single frame position of the other while the tapes are moving at a constant rate of speed. The tapes cannot be stopped in the correct position for a transfer because motion past a magnetic head is required to read or write information. Thus if both machines try to move one frame's worth from a dead start position, the startup time lag would affect the quality of the first part of the frame.

Under computer control it is possible, while both tapes are moving, to find and transfer one frame over to the other in a correct position. But before the next frame can be brought in, the master tape will have advanced too far, so it must be stopped, backed up past the position of the last insertion, and then started up again so the tape is at full speed and ready to receive the next frame, when the operation will again have to be repeated.

Some of the newer machinery has the head spin instead of the tape, but in general the problems are the same. At best, this process requires a great many hours of expensive editing time with expensive machinery.

Even then there is still another problem to be resolved with the tape because the producer still has the problem of checking each still frame to see if it is in the correct position with the right quality. Thirty different still frames per second will flow by the viewer in a blur if any attempt is made to view the tape at normal speed, so the frames must be frozen by halting the tape and spinning a magnetic head against the tape frame while it is being read and viewed. This spinning head, unfortunately, quickly tends to degrade the image quality of the tape.

Thus the only realistic method for handling individual tape frames is to put them one at a time on a magnetic disc under computer control. Then when they are all in proper order, they can be transfered to the master tape in one pass. Then the frames on the tape can be checked by reading them back into the magnetic disc, where the copy of the contents of the master tape can be examined frame by frame to see that the tape has them recorded accurately.

The state of the art in television production has adequate hardware to make a master tape for a videodisc project, but as we have seen, the machinery is quite complex because the industry was not built around the concept of transfering individual still frames from tape to tape. Thus unless a production team has either a great deal of capital or access to a well equipped television

studio without paying the normal editing costs, it will undoubtedly have to do its mastering on film.

Film presents some special problems of its own:

(1) Building either the final master or a prototype by splicing many individual still frames together causes a focus problem when the spliced film is pressed against the master during the copying process. The way splices are generally done leaves a double thickness of film along the edge of the splice. This pushes the edge of the frame out of focus by the width of the film itself. Normally, the splicing problem is never faced in viewing movies because 24 rather similar frames go by every second. However, where individual frames are spliced together and are different, even if a group were placed in sequentially, the first few frames near the splice would show focus problems when shown in the freeze frame position. There are some sophisticated splicing techniques that can avoid some of these problems, but a production team will be well advised to avoid splices if possible. One such option is to use an optical printer.

(2) Since films normally run at 24 frames per second, and tape runs at 30 frames per second, when the film master is given to the center which will press the disc, the film frames will be duplicated more frequently on the master tape they make prior to making the stamping master. For reasons too complex to explain here, a very careful coding

operation must take place to ensure that the still frames that are produced on the final tape master are usable. Without special coding abilities, a good percentage of the frames would be a combination of two different individual still film frames, and hence would be unintelligible. The implications of this potential problem are that only those corporations who have the most advanced machinery to solve this coding problem, such as MCA, should do the disc stamp operation.

(3) When using film, metal clips of the correct size will have to be clipped at the appropriate still frames where an automatic stop is planned. Metal clips will not be required if the master film is 35mm, but in working with 16mm these clips will probably be necessary. Thus when the mastering specifications are drawn up, communication with the group that will do the stamping process should be effected in order to plan for the use of the automatic stop feature.

(4) There has been a fair amount of publicity about a chapter stop device which theoretically would be used like a tab key, using the search control. The production team should realize that, since the disc is moving so rapidly in the search mode, it will probably not be able to stop within 400 frames of the intended location, or within 13.3 seconds of playing time.

(5) In making a film master, the production team should be careful to avoid going through too many copies because a

great deal of quality will be lost in each generation beyond that of the original.

(6) The authoring team should be careful to arrange for an absolutely precise counting of frames, including all of those in the motion sequence, so that when branching frames are used which specify a frame number to branch to, the actual branch number and frame number coincide. Remember that the frame numbers that appear on the screen will be inserted automatically when the final mastering tape is being made preparatory to cutting the stamping disc. At this time the authoring team will not be present to check and see if the assigned numbers are the same as those they have referenced in their branching frames.

These are some of the difficult problems that have surfaced in the early authoring attempts, but the field is so fluid and the knowledge so sparse that there are very few certainties, and there very well may be some assistance from the videodisc corporations and the supporting industries as the field matures.

IV. RECOMMENDATIONS FOR NIE

Without making specific project recommendations, the author feels there are some useful guidelines for the National Institute of Education to consider in supporting possible videodisc projects:

(1) The government should not invest money in areas where the normal business market will successfully develop projects as a matter of course. In the case of the videodisc, there are two business areas that will have an influence on the educational market:

(a) The hardware manufacturers, such as Philips, MCA, and others.

(b) The publishers of educational materials, such as the traditional publishing companies like McGraw-Hill, Harcourt Brace Jovanovich, etc.

There is a possible third area, which is the entertainment industry, but this group is not likely to commit very substantial sums to educational enterprises. There are a few weak points that need buttressing, given the dynamics of the current industries. Publishers traditionally have very little R&D funds, so they will be hard pressed to expend very much capital in this direction. Indeed, their profit margins are too slender to have excess capital for strenuous research efforts because much of their publishing is so risky that their whole industry might be described as a marginal R&D operation. The hardware manufacturers have spent millions in bringing their hardware to fruition and are not interested either in expensive educational R&D projects.

Given these facts, the government might consider supporting the development of some educational programs, particularly in the basic skills area, so that educators might learn how to use the strengths of this new technology. The project should also have the goals of offering objective data as to the effectiveness and cost of the instruction.

Bennion and Schneider have done an excellent cost analysis for videodisc instruction, and Bennion's comments from another study are included at great length in Appendix B of this document. The general findings indicate that if enough discs are made simultaneously and used a frequent number of times by students, then the expense will be extremely cost effective. What their work suggests, in other words, is that the cost will be extremely favorable if attractive courseware can be developed that is actually used by the students and general public. The central problem, then, is developing outstanding courseware that serves a national need. As we have seen, the videodisc has the potential, and the costs are not a technical problem.

Once the lessons are learned, the costs established, and the effectiveness of the technology proven, the path would be clear for the publishers and hardware companies to assimilate the task of successfully using this technology.

(2) In choosing projects to sponsor, the National Institute of Education should be careful to fund the programs with two

considerations in mind that inevitably are present when working with high technology:

(a) Developing courseware for high technology projects requires a high minimum mass of capital.

(b) The projects take many years and should be funded with this in mind.

In other words, rather than dissipating R&D funds to many sites, a project such as this should require a high funding level for many years to be effective. The alternate funding strategy, in failing to provide the minimum mass, frequently keeps the government involved in the projects years more than they need to be had a larger mass of capital been provided initially.

(3) In a sustained educational project in the basics, the government may still have to fund some prototype hardware as part of the project. Some tape editing equipment that could handle still frame manipulation is a necessity, and in the absence of a firm market the larger corporations may ignore this need. Another need is the construction of an inexpensive laser editing device that would allow universities to make single copies of their preliminary courseware before sending the finished product out to be stamped. North American Philips has developed some prototypes for this, but is reluctant to complete the work because of market considerations. In the absence of these two machines, colleges, universities, and educational

institutes may be reluctant to get into the courseware development business because of the constraints I discussed in the section on mastering problems.

APPENDIX A

A BRIEF DISCUSSION OF THE STRENGTHS AND WEAKNESSES OF VARIOUS EDUCATIONAL TECHNOLOGIES

Most of the educational projects involving the use of technology concentrate on developing materials for just one of them. In the years ahead, because technology will assume much greater importance due to its cost and productivity benefits, educators will have to be more sensitive to designing their programs with many technologies in mind. In order to help clarify these, we have put together a brief discussion of the strengths and weaknesses of the standard technologies:

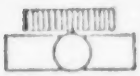
Book

The book is by far the most successful use of technology in aiding education to date. It has random access capabilities, it is portable, and is relatively inexpensive. The major disadvantages of the book are:

(a) It is not interactive.

(b) It lacks motion and sound.

(c) It cannot be personalized or modified very easily.



Slide tape

The slide tape and overhead projector allow personalized materials to be presented in a powerful graphic form. They frequently are more economical than printing copies for the viewing parties, and with some care sound can be added as a permanent feature. The shortcomings of the medium are:

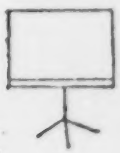
(a) It requires working equipment in a special environment that can be darkened.

(b) It cannot individualize instruction.

(c) It is not interactive instruction.

(d) There is traditionally only one set of materials, and these are maintained by the instructor.

(e) It is difficult to have rapid random access ability.



Movie

The movie adds the powerful dimension of sound and motion, but it has some fundamental shortcomings:

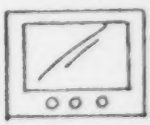
(a) It requires a special environment and machinery.

(b) The cost of maintaining the film and equipment is expensive and is a burdensome task.

(c) It cannot individualize instruction.

(d) It is not interactive instruction.

(e) It is difficult to have random access ability.



TV

Television once appeared to have the greatest potential of any of the media for instruction. It has many obvious advantages including the expense of the equipment, the lack of communications costs, and the fact that it is already present in almost every home. After a number of years of usage, however, there are some fundamental shortcomings in the use of television broadcasting as an instructional technology. While the technology

increased the productivity of the teacher, it is not a very productive approach for the learner. Some of the shortcomings from the productivity of the learner are as follows:

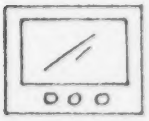
(a) He must arrange his time to be available at the moment the material is being broadcast.

(b) The presentation is in a serial form so that he must wait patiently for the appropriate significant moments. Even in reading a newspaper one has random access ability that television lacks.

(c) He cannot stop the material and review it if he has suddenly found it too difficult.

(d) The materials being presented rarely are at the appropriate level for his individual needs at that point. He cannot have an easier or harder version of what he is studying, and he cannot go into any aspect of it in any depth.

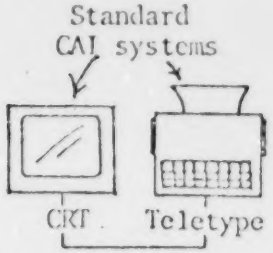
(e) He cannot interact with the materials and get a response as he attempts learning trials.



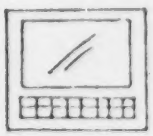
Tape cassette

The use of a tape cassette that a student can attach to a videotape player gets rid of the first disadvantage listed above where the student must be available at the moment the material is being broadcast, and although he can stop sections of the tape, rewind them and replay

a section he has just seen, most of the disadvantages of the straight television approach remain. Using a tape cassette is probably easier for a student than running a movie projector, but the medium is still not interactive or capable of being individualized to any significant degree.



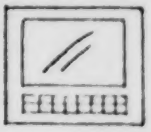
The strengths of a standard computer assisted instruction approach with either CRT or teletype terminals is well known. Instruction can be individualized and made highly interactive. There have been some graphics materials added with special graphics terminals, but for the most part the standard CAI approaches lack the ability to use the motion picture sound and color format that can be so appealing to a student. These systems also require a fair amount of communications costs when the materials are placed at a distance from the host computer.



TICCIT TV

As has been discussed above, the TICCIT system has done an excellent job in developing interactive individual frame instructional potential for the color television screen, but because of the storage requirements of interactive audio and motion picture materials, it has been

unable to combine the power of these still frames with interactive color motion picture materials.



TV game with micro keyboard

During the next few years one of the exciting new delivery systems will develop as an offshoot of the home video game market. Microprocessors with keyboards using cassettes for the storage medium will continue to be designed to attach to the home television screen. These devices will have some remarkable potential for small instructional projects. They will allow the users to learn programming and no doubt various cassettes will be developed with CAI programs on them. The game cassette storage size will not allow very many segments of color television type-material to be stored. In addition, the cassette will have the usual random access problems that is a function of this technology.

Videodisc I with player

Videodisc II with micro keyboard & player

The videodisc with its player differs primarily from the other techniques because it combines the strengths of a number of them, thus overcoming their individual weaknesses. Because each frame is numbered, the videodisc has a rapid random access capability, and because it can store 54 billion bits of

information it is capable of maintaining a combination of individual instructional frames and moving picture presentations. When coupled with the microprocessor and a keyboard, the videodisc will become a fully interactive instructional data base that will offer individualized instruction to the student with answer processing capabilities. Since most schools and homes have color television sets, the device obviously will have broad user accessibility. Furthermore, since the Philips disc is read by a laser beam, it should never wear out. Thus not only will the disc be very inexpensive to make and purchase, but also to maintain. The only shortcoming of the videodisc is that it is a ROM (Read Only Memory) that will not be able to be modified by the user. This means that when a curriculum is adjusted, a new videodisc master will have to be made.

Thus we see that each of the technologies has special strengths and weaknesses, but overall the videodisc should have the ability to combine the best features of a number of the others. The hardware will be inexpensive and yet, while retaining the emotional impact of motion and sound inherent in a film or television medium, it will also add the ability to offer individualized and interactive instruction for the students that has been available only with computer assisted instruction.

A P P E N D I X B

COST ANALYSIS FOR INTERACTIVE COURSEWARE

This appendix is compiled from the work of two authors, J. L. Bennion and E. W. Schneider. Specifically, this information is taken almost verbatim from a manual entitled "Authoring Procedures for Interactive Videodisc Instructional Systems" written by Junius Bennion and published in 1976 by WICAT Incorporated, 1160 South State Street, Suite 10, Orem, Utah 84057 and 111 East 85th Street, Room 29E, New York, New York 10028.

General Factors Relating to Cost and Time Budgets

Undoubtedly one of the major factors in selecting the type of videodisc system to be used will be the cost of development and the length of instruction that can be presented on a single videodisc. The 30-minute videodisc (all motion) can be extended to many hours of instruction depending upon the number of still frames that are inserted into the motion sequences. For example, each minute of motion when transformed into still frames will provide 1800 still frames. When viewed for an average of 10 seconds per frame this converts to five hours of instruction. Even if it is assumed that each still frame will require another frame for storing digital codes, a videodisc devoted entirely to still frames would provide 75 hours of instruction. Other ratios of still frames to motion frames indicating the resulting hours of instruction are shown in Figure 1.

Because still frames are more expensive to produce than motion frames the production cost of a single videodisc will increase greatly if the ratio of still frames is large. However, the cost per hour

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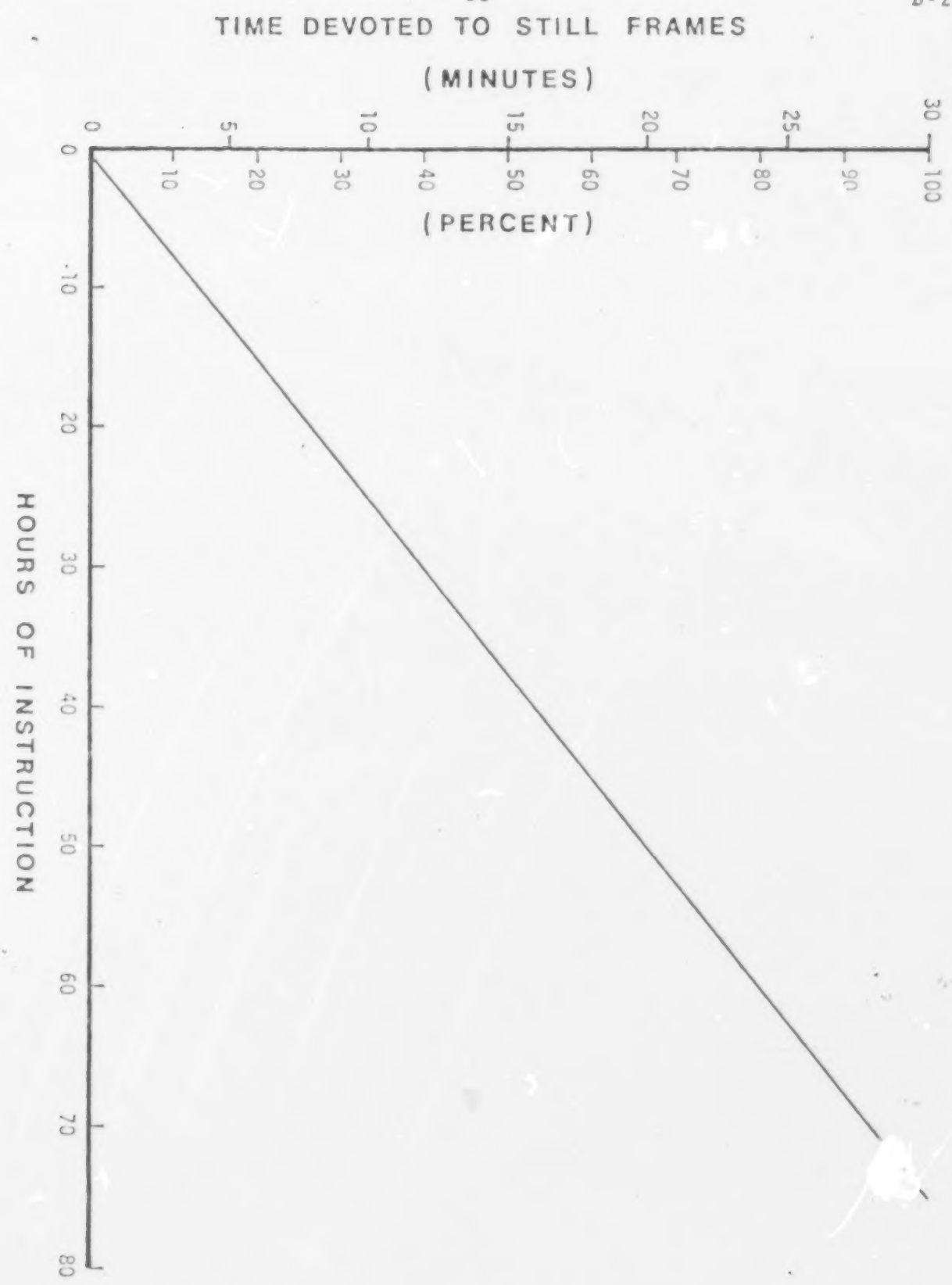

FIGURE 1. The Resulting Hours of Instruction for Various Ratios of Still Frames to Motion Frames.

of instruction will remain fairly constant because the length of instruction is increased when more still frames are used. This effect is demonstrated in the following cost model which calculates the cost per hour of instruction for interactive videodisc courseware. This model is from Bennion and Schneider (1975).

$$\text{Cost of Instruction per Hour} = \frac{1}{\text{Hours of Instruction}} \left[\frac{\text{Development Costs}}{\text{Market Size}} + \text{Production Costs}\right]$$

The ratio of still frames (sf) to motion frames (mf) and the costs for producing still frames (sfc) and motion frames (mfc) are related to the hours of instruction and the development and production costs in the following equation:

$$\text{Cost/Hr.} = \frac{1}{.5\left[1 - \frac{\%sf}{100}\right] + \frac{\#sf}{720}} \left[\frac{(sf)(sfc) + (mf)(mfc) + 500}{\text{Market Size}} + 1\right]$$

The assumptions implied in the above cost model are the following:

1) Each still frame is viewed for an average of 10 seconds (360 frames per hours).

2) Each still frame is supported by one other frame that is used for codes; therefore a total of 720 frames are needed for one hour of still frame instruction.

3) The production costs for a single videodisc are $500 and drop to $1 per disc for large quantities according to the following:

$$\text{Production Costs (per videodisc)} = \frac{\$500}{\text{Market Size}} + \$1$$

If we assign development costs for still frames (sfc) and for motion frames (mfc) we can calculate hourly costs of instruction for a variety of market sizes. We have done this for market sizes of 100; 1,000; 10,000 and 100,000 videodiscs, using sfc=$10 and mfc=$0.20. Figure 2 shows the resulting curves that are derived from using the cost model and the assumptions for single frame and motion frame costs listed above. Of course, as the number of discs that are produced increases, the unit cost decreases accordingly.

As observed in this figure, the cost of one hour of interactive instruction is related to the number of videodiscs produced and to the percent of the disc devoted to still frames. It is interesting to note that when more than about 15 to 20 percent of the disc is devoted to still frames the cost of instruction per hour is essentially constant. This is due to the fact that as the costs of producing interactive videodiscs increase the length of instruction also increases, with the result that the cost of instruction per hour remains almost constant. Therefore, the type of content and the length of instruction desired can be manipulated over wide ranges without changing the hourly cost of instruction.

The calculations represented in this figure are for a single one-time use of the disc. Of course if the disc is used many times, as in an educational setting, then the cost of instruction due to the cost of videodisc courseware would decrease accordingly. For example, if only 100 discs were produced but each disc were used 100 times, then the hourly cost of instruction would decrease to one hundredth of the one-time-use cost. This would essentially be the same curve as that for 10,000 discs (i.e., approximately 75¢ per hour). Corres-

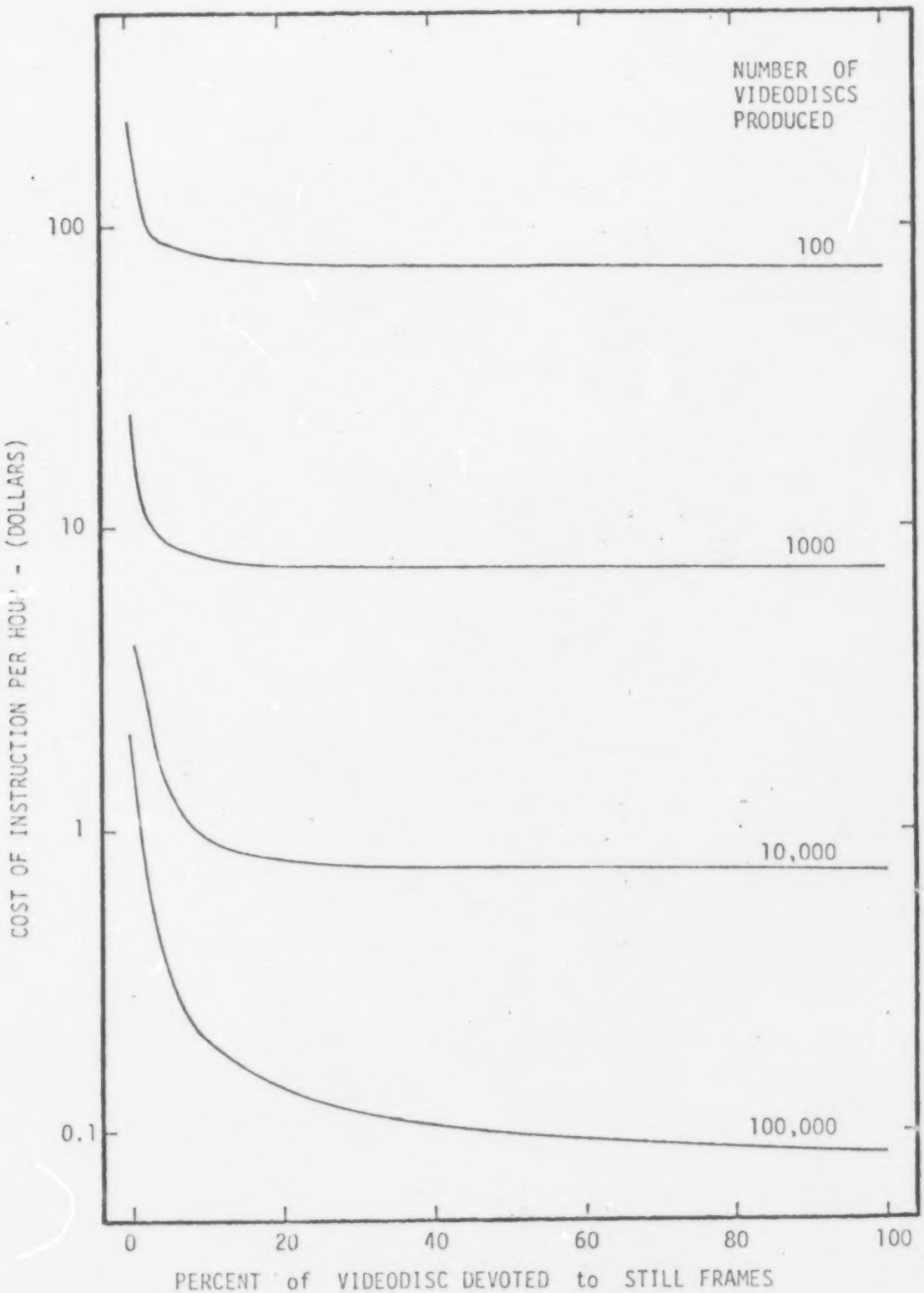

FIGURE 2. Estimated Hourly Cost for Interactive Instruction.

pondingly, If 1,000 discs were produced and used 100 times each, the cost for instruction would be reduced to less than ten cents per hour. Of course, these results are based on some rather crude cost figures that need to be refined, but they indicate the definite possibility of producing high quality interactive instruction at very low cost when the production run is large and/or when each disc is used many times. No other interactive instructional system that provides motion, color and audio is capable of operating at such low cost. The flexibility in scheduling and location plus the high quality of instruction and low cost per hour that appear to be realizable with the interactive videodisc system may permit this new technology to have a great impact on the educational environment in the near future. Although the low cost is attractive, the production of high quality interactive courseware is essential for ultimate acceptance and success of this new approach to instruction.

Making a Cost Analysis for Interactive Courseware

In addition to the several analyses discussed above, it will be necessary to perform a cost analysis before starting the authoring task and to make final selections of media by comparing costs with desired outcomes. Since interactive videodisc instructional delivery systems are new and substantially different from other media, it will be necessary to consider such factors as availability of interactive hardware, availability of interactive editing and encoding systems, volume of production, cost of instruction per hour, length of instruction per videodisc, and other factors. These factors will

determine what configuration of interactive videodisc system is finally selected so that the authoring of courseware can be started.

The relationships between several factors of interest in planning for interactive videodisc authoring and instruction are expressed in the following equations:

1) $\frac{\text{Instruction Time}}{\text{Per Videodisc}}$ = (Motion + Still Frame + Code Frame) Time

When expressed in minutes, these factors may be written:

2) $$\frac{60H}{V} = 30\left(1-\frac{s}{54000}\right) + \frac{sv}{60(1+d)} + \frac{sd}{1800}$$

where:

H = Hours of instruction for the entire course.

V = Number of videodisc masters to be developed.

s = Number of still frames used for instruction.

v = Average time (in seconds) that each still frame is viewed.

d = Ratio of the number of code frames to still frames.

Equation 2) can also be expressed in terms of s as follows:

3) $$s = \frac{60H - 30V}{V\left[\frac{v}{60(1+d)} + \frac{d}{1800} - \frac{30}{54000}\right]}$$

Since, for interactive instruction, the number of still frames (s) is the main factor that extends both the length of instruction and the development costs, it is essential that this number be estimated carefully before extensive authoring is begun. If numerical

values for the other factors in equation 3) can be provided, then s can be found, thus leading to other cost estimates needed for planning purposes.

Two products that should result from the many analyses that were described in the previous section should be outlines of (1) the content, and (2) the presentation order or strategy. With these outlines and the basic course design, the author should be able to provide estimates for the total hours of instruction (H) and the average still frame viewing time (v). The number of videodiscs (V) will depend upon the need for motion sequences vs. still frames and upon the type of interactive videodisc delivery system to be used. The plots in Figures 1 and 2 can be used as a guide in deciding what percent of each videodisc should be devoted to motion. Of course, V must be assigned only integer values. The value for the ratio of code frames to still frames (d) will vary from zero to one. Code frames are not required for the consumer model; therefore, d=0 for this system. It is suggested that, for the educational model with TICCIT learning keys and a microprocessor, d=1.0. These values for d are adequate for preliminary planning but may need to be revised as experience is gained in authoring and producing interactive videodiscs.

The author should develop a complete cost estimate based upon the estimates described above prior to beginning the authoring task so that the scripting and production efforts may be kept within the limits desired. A form that organizes this cost estimation data is presented in Figure 3. The author should enter estimates where

INTERACTIVE VIDEODISC COST ANALYSIS

Course Title _____ Author _____

No.	Item			Per Videodisc Master (a)	Course Total (a)(V)
1.	Hours of Instruction	(estimate)	H		_____
2.	Number of Videodisc Masters	(estimate)	V		_____
3.	Average Still Frame Viewing Time (seconds)	(estimate)	v		_____
4.	Ratio of Code Frames to Still Frames	(estimate)	d		_____
5.	Number of Videodiscs to be Produced	(estimate)	M	_____	_____
6.	Number of Uses Expected	(estimate)	U	_____ =	_____
7.	Number of Still Frames $s = \frac{60H - 30V}{V\left[\frac{v}{60(1+d)} + \frac{d}{1800} + \frac{30}{54000}\right]}$		s	_____	_____
8.	Number of Code Frames $c = sd$		c	_____	_____
9.	Number of Motion Frames $m = 54000 - (s+c)$		m	_____	_____
10.	Development Costs for Still Frames $C_s = s \times \$_s$ $\$_s =$ _____		C_s	_____	_____
11.	Development Costs for Code Frames $C_c = c \times \$_c$ $\$_c =$ _____		C_c	_____	_____
12.	Development Costs for Motion Frames $C_m = m \times \$_m$ $\$_m =$ _____		C_m	_____	_____
13.	Total Development Costs $C_d = C_s + C_c + C_m$		C_d	_____	_____
14.	Production Costs $C_p = \$500 + (\$1.00 \times M)$		C_p	_____	_____
15.	Total Cost for Production and Development $C_t = C_d + C_p$		C_t	_____	_____
16.	Cost per Hour for Interactive Instruction $C_h = \frac{C_t}{M \cdot H \cdot U}$		C_h	_____	_____

FIGURE 3. Form for Calculating Costs for Interactive Videodisc Courseware.

indicated and calculate each step using the formulas provided. A copy of this form with all of the cost data computed should be provided with the script for the guidance of the production team and others involved in managing the resources needed to author and produce interactive videodisc courseware.

In addition to estimating H, V, v, d, M and U, estimates are needed for the average cost per frame for still frames ($\$_s$), code frames ($\$_c$) and motion frames. ($\$_m$). In the earlier analysis, the costs for code frames and still frames were not separated and a value of $10 per frame was used for both. Motion frames were estimated to cost 20¢ each. For preliminary planning it is suggested that the following cost estimates be used:

$$\$_s = \$10,\ \$_c = \$5, \text{ and } \$_m = \$0.20$$

Again, it is certain that experience will provide more accurate cost estimates, but little applicable experience is available at present.

Using the above estimates and the steps in Figure 3, three tables of hourly costs for interactive instruction have been calculated. The first table (Table 1) represents a small two-hour course on one videodisc with mostly motion frames and no code frames. This course represents the type of interactive videodisc that probably would be used on the consumer and educational models. The second table (Table 2) represents a 10-hour course on two videodiscs that is typical of interactive instruction given on the educational model where some code frames would be required. The third table (Table 3) represents a 100-hour course on five videodiscs that might be presented on the educational system.

Table 1. Cost per Hour for a Short Interactive Videodisc Course (C_h)

No. Videodiscs Produced (M)	Number of Times Used 1	5	10	25
100	$313.075	62.615	31.308	12.524
1000	31.758	6.352	3.176	1.270
10 000	3.626	0.725	0.363	0.145
100 000	0.813	0.163	0.081	0.033

H = 2	d = 0	m = 48774	C_m = $9755	$\$_c$ = —
V = 1	s = 5226	C_s = $52260	C_d = $62015	$\$_m$ = 0.20
v = 10	c = 0	C_c = 0	$\$_s$ = 10.00	

Table 2. Cost per Hour for a Medium Interactive Videodisc Course (C_h)

No. Videodiscs Produced (M)	Number of Times Used 1	5	10	25
100	$70.253	14.051	7.025	2.810
1000	7.115	1.423	.712	.285
10 000	.802	.160	.080	.032
100 000	.170	.034	.017	.007

H = 10	d = 0.5	m = 46764	C_m = 9353	$\$_c$ = 5.00
V = 2	s = 4824	C_s = 48240	C_d = 69653	$\$_m$ = 0.20
v = 10	c = 2412	C_c = 12060	$\$_s$ = 10.00	

Table 3. Cost per Hour for a Long Interactive Videodisc Course (C_h)

No. Videodiscs Produced (M)	Number of Times Used (u) 1	5	10	25
100	$21.237	4.247	2.124	.849
1000	2.133	0.427	0.213	.085
10 000	.222	0.044	0.022	.009
100 000	.031	0.006	0.003	.001

H = 100	d = 1.0	m = 26470	C_m = 5294	$\$_c$ = 5.00
V = 5	s = 13765	C_s = 137650	C_d = 211769	$\$_m$ = 0.20
v = 10	c = 13765	C_c = 68825	$\$_s$ = 10.00	

These tables indicate that the cost per student hour for instruction is very low when the number of videodiscs produced is 1,000 or more and/or when the number of uses increase substantially above five uses per videodisc. The percent of the videodisc devoted to the combination of still and code frame is 9.67%, 13.4% and 51.0% for Tables 1, 2 and 3, respectively. The amount of time available for motion sequences per videodisc is 27, 26 and 15 minutes for Tables 1, 2 and 3 respectively. Similarly, the percent of time devoted to motion per course is 22.5%, 4.3% and 0.245% for Tables 1, 2 and 3 respectively. This last item indicates that for lengthy courses designed to fit on only a few videodiscs the main bulk of instruction must be given on still frames.

As illustrated in Figure 2, the hourly costs are nearly constant over wide ranges of percentage of the videodisc devoted to still frames. This effect means that little is to be gained in cost reduction by making an all still frame disc and that discs should be designed to fit the needs for motion sequences and length of study time desired.

Since audio is currently restricted to motion frames, most of the instruction for a very lengthy course must be presented on a visual format. Eventually, however, it may be possible to digitize audio on code frames that will permit many seconds of audio to be decoded from one frame. Some techniques to do this already exist. However, the cost and complexity of both the recording and the playback hardware would increase. With the tremendous growth in computer technology such techniques are definitely possible at low cost and may eventually be used extensively for extending instructional as well as entertainment programming on future videodisc systems.

Finally, it should be stated that the capability of the videodisc to mix motion and still frames has produced a new dimension for audio-visual media. The best mix of still and motion frames will depend on many factors that must be analyzed by techniques different from those used in analyzing instruction for traditional audio-visual media.

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